CENTRE OF STUDIES FOR BUILDING SURVEYING
FACULTY OF ARCHITECTURE, PLANNING AND SURVEYING
UNIVERSITI TEKNOLOGI MARA

THE APPLICATION OF RAINWATER HARVESTING TO OVERCOME WATER CRISIS IN KLANG VALLEY

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"I hereby declare that this academic project is the result of my own research except for the quotation and summary which have been acknowledged"

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ABSTRACT OF THE THESIS

THE APPLICATION OF RAINWATER HARVESTING TO OVERCOME WATER CRISIS IN KLANG VALLEY

Muhammad Imran Bin Pandak Othman

Centre of Studies for Building Surveying,

Universiti Teknologi Mara, 2013

The purpose of this study is to identify potential of rainwater harvesting to overcome water crisis in Klang Valley. The studies examine the responses of 20% occupants of case studies which are Department of Irrigation and Drainage, National Hydraulic Research Institute of Malaysia and Ministry of Energy, Green Technology and Water. The paper looks at knowledge of people, benefits, system that used for the building, problems and barriers of rainwater harvesting. The data will gather using the questionnaire which will be analysed using the Statistical Package for Social Sciences SPSS version 21. The paper shows that rainwater harvesting has lot of benefits that public not acknowledge the potential. The paper provides original and useful information for developing rainwater harvesting system with effective and efficient.

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THE APPLICATION OF RAINWATER HARVESTING TO OVERCOME CRISIS WATER IN KLANG VALLEY

CHAPTER 1

1.1 INTRODUCTION

Earth's surface approximately covers by one quarter of land and another three quarter covers by water. In 2025, two thirds of the world's population will facing water shortage and that was stated by United Nations. Nowadays, urban dweller has 18,000 additional in the world in every day and half of the world's population live in urban areas. The former Secretary-General of United Nation, Kofi Annan was stated in his speech during World Day for Water 2002, 1.1 billion people may lack access to safe drinking water, 2.5 billion people have no proper sanitation access, and over 5 million people die every year regarding water-related diseases, which is 10 times the number killed in wars. Statements above shown water are not a new issue that shall be discuss and should have drastic action to overcome water crisis (United Nation, 2002).

Water is an important element in our life for heavy-duty industries, manufacturing, clinical purpose, commercials and the last but not least is the domestic purpose such as drinking, cooking, washing and etc. By abundance amount of population makes clean water demand drastically arise and it's become scarcity in population. Malaysia is a tropical climate nation which means humid tropics region and receive plentiful rainfall every year is facing encounter acute water crisis especially in urban areas such as Klang Valley. Water crisis in Klang Valley is the current scenario and it becomes disputation at each level class from publics until the ministries in Parliament. Decision has make, by construction Langat Dam 2 can solve water crisis in Klang Valley but its take more several years to finish up the dam and it will burden the population for their routines. To pursue population in Klang Valley with short-term process, rainwater harvesting has been recognised as an effective method, has simple technology and environmental friendly. Rainwater harvesting is not a new system that used in Malaysia, it has been used in Sandakan to overcome water crisis at there but this system does not separate widely in our region. Malaysia is moving forwards to achieving a goal, that become developed nation status by the year 2020 and this goal was set by the fourth Prime Minister, Tun Dr. Mahathir Mohamad. Our goal should move along with income rate, public harmonies, and improvement technology to arising public comfort.

Rainwater harvesting is a technology used to collet, convey and store rain water for daily life purpose from relatively clean surface such roof. The water generally stored in a rainwater tank or directs to recharge groundwater. Rainwater harvesting has lots of benefits at high among rainfall areas such as it can reduce rain storm and replenishment ground water level. Rainwater harvesting has been practiced for Malay traditional culture. They used rainwater for domestic water and water for livestock and small irrigation. Now rainwater harvesting has gained much on significance as overcome water crisis, water-saving and simple technology. Rainwater harvesting system relevant apply in Malaysia because among of rainfall is high. Based on Malaysian Meteorology Department, Malaysia receive highest total rainfall amount was recorded at Senai Meteorological Station with readings of 341.6 mm while the lowest total rainfall amount was recorded at Kuala Terengganu Climatological Station with readings of 79.9 mm in August 2012.

According to Gould and Nissen-petersen (1999), collecting rainwater from rainfall events can be classified into two broad categories: land-based and roof-based. Land-based rainwater harvesting occurs when runoff from land surfaces is collected in drainage, ponds, tanks and reservoirs. Roof-based rainwater harvesting means rainwater will be collects from roof surfaces and gutter which usually provides a much cleaner source of water that can be also used for drinking but in

Malaysia not widely applied. In Malaysia, roof-based rainwater harvesting only applied at green building and certain residential such as in Bangi, Selangor and Sandakan, Sabah. Green building in Malaysia, rainwater harvesting only used for flush toilet, gardening and not for domestic purposed. In Klang Valley, land-based rainwater harvesting and through to water treatment before used for main clean water supply by underground pipes to domestic buildings and non-domestic buildings. The government was set up and specified the location for that purpose such as Hulu Langat dam, Semenyih dam and other few dam to fulfil usage in Klang Valley.

Nowadays, population in Klang Valley was increasing drastically due to development and employment opportunities. Based on Economic Transformation Programme (ETP), population in Klang Valley will increase over than six million peoples in 2020 and clean water supply not enough to provide for all users in Klang Valley. Therefore, crisis of clean water occur and government impasse to find the solution. By introducing roof-based rainwater harvesting is away to overcome water crisis in Klang Valley. Reason for choosing rainwater harvesting are rainwater is a free source and relatively clean and with proper treatment it can be even used as a potable water source and among of rainfall is high. Rainwater harvesting can be high-quality drinking water sources after pass through filtering process and relieves the pressure on sewers and the environment by mitigating floods, soil erosions and replenishing groundwater levels.

1.2 ISSUE OF THE TOPIC / PROBLEMS STATEMENT

Nowadays, water crisis is biggest issue in world and was stated in The 2005 World Sustainable Building Conference, Tokyo, 27-29 September 2005. In the conference was discussed about scarcity of water and current scenario water crisis in Malaysia. The worst water crisis in Malacca in 1991 which the people at that area facing water rationing for three months and the potential experienced of population in Malacca will face to the population of the Klang Valley within three years from now.

Based on studies, National Water Resources Study (NWRS) and Syarikat Bekalan Air Selangor (Syabas) recently stated that the water crisis will become critical at the Klang Valley in 2013. Ministry of Energy, Green Technology and Water (KTTHA) has issued a warning that the problem of water storage in Selangor, Kuala Lumpur, and Putrajaya now reached the critical level.

Imminent water crisis in the Klang Valley has again warned by The Energy, Green Technology and Water (KTTHA). By June 30, 34 treatment plants in Selangor was produce exceeding the capacity consumption and the numbers is 50 million litres (The Star, July 3 2012). All the plant produced 4,420 million litres per day in maximum consumption from ministry statement and water disruptions will occur in Selangor, Kuala Lumpur and Putrajaya. The period between June 25 and July 1, the average demand of water in all three areas was around 4,369 million litres per day, it nearing reach maximum production capacity. In Bandar Botanic, Klang, water several disruptions in past months due to low water pressure on that area (New Straits, July 16, 2012).

1.3 OBJECTIVE OF STUDY

The aim of this research is to study the potential of rainwater harvesting system in overcome water crisis in Klang Valley. To achieve this aim, the following objectives have been determined.

1. To identify system of rainwater harvesting that used at case studies building.
2. To identify people knowledge about rainwater harvesting system in Klang Valley.
3. To identify the benefits of rainwater harvesting system in Klang Valley.
4. To identify problems, barriers or any inadequacy that associated with rainwater harvesting system.

1.4 SCOPE AND LIMITATION OF STUDY

The scope of this study will focus on building that has been used rainwater harvesting system include government building and private in Klang Valley. In Malaysia, rainwater harvesting is used as secondary water supply for the building and not for main water supply to building. Rainwater harvesting used to flushing toilet, landscaping, washing but not for drinking water. Identifying function, operation, benefits, and barriers to comply this system in building also included in this study.

In this study may include interview respondents that have experience in application of rainwater harvesting system and users of rainwater harvesting. Identify types or any branches of rainwater harvesting system will put in literature review. In the result and conclusion of this study, the potential of rainwater harvesting system to overcome water crisis in Klang Valley is accepted or vice versa.

Limitations for this study are limited numbers of building and housing that implement rainwater harvesting system. Besides that, approval to access the building might be difficult because the building was occupied and security precaution on the building. Other than that, less of public knowledge about rainwater harvesting includes in limitation for this study.

1.5 Research Design / Methodology of Study

Plan to carry out the survey:

1) Literature review

i. Books

ii. Internet

iii. Interview

iv. Journal

2) Problem Statement

3) A case that involved operation rainwater harvesting system

4) Objective: To determine effectiveness rainwater harvesting system and appropriate the system to population.

Activity: 1. Literature review

2. Interview

3. Distribution of Questionnaire

5) Data Analysis

CHAPTER 2

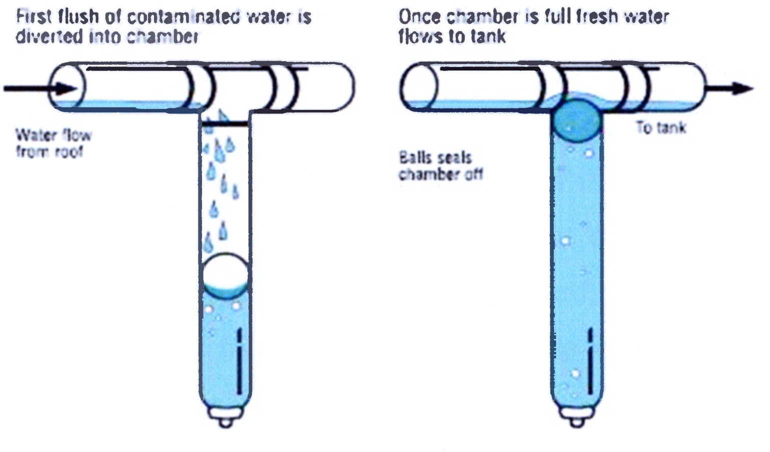
CHAPTER 2

2.1 INTRODUCTION

Rainwater harvesting is a system collecting and store of rainwater for certain purposes. In this chapter, explanation in details of rainwater harvesting system such as the history, elements of rainwater harvesting system, quality of rainwater harvesting, contamination in rainwater harvesting, advantages and disadvantages. This chapter also as a platform to achieve objective of study by review previous journal and research.

2.2 HISTORY OF RAINWATWER HARVESTING SYSTEM

Historically, rainwater harvesting is provided for drinking, landscape watering and for agriculture purpose (Waterfall, 2006). Rainwater harvesting is system collecting rainwater for those purpose and it was implement before water distribution system introduced in Malaysia. Harvested rainwater has been the main water sources during the time because it used simple method and it was primary water supply during that time. Collection of rainwater mostly from roof surface and in certain rainwater was collected directly from sky and it used directly without any treatment and filtration. After water conveyance introduced, rainwater harvesting slowly disappeared and forgotten. Recently, population increasing drastically due to development and government policy makes scarcity of water demand arising in Malaysia. Presently, rainwater harvesting is the solution for this crisis and harvested rainwater can be improved in quality due to improvement and advance in technology. Harvested rainwater secured from contamination after passing treatment and filtration (Mosley, 2005).



(Source: harvesth2o)

The government take a step forward on the application of rainwater harvesting by introduced policy and incentives for rainwater harvesting in Malaysia. This guideline was endorsed in 1999 but the response is very disappointed among contractors and developers. On 16 March 2006, the Prime Minister announced that rainwater harvesting would be made mandatory to large buildings and the aims to examine the present policies on rainwater harvesting, to identify possible obstacle and to provide suggestion for a successful implementation of rainwater harvesting policy in Malaysia. In five years, observation and research on rainwater harvesting was made based on the guidelines, the Ministry set up another cabinet paper to the National Water Resources Council to encourage government buildings to install a rainwater collection and utilization system. The Council has later announced that rainwater utilization is to be encouraged, but not mandatory, in all federal and state government buildings, there is a need for rainwater utilization campaign and to provide a solution for prevention of mosquito breeding. The result of the cabinet paper, only two of government buildings were implement rainwater harvesting and the buildings are Department of Irrigation and Drainage and the Ministry of Energy, Water and Communication (Shaaban et al., 2008).

Starting from the guideline endorsed in 1999 until now, among of local authority implement of rainwater harvesting is small with exceptions in Johor and Penang. Few local authorities such as Sandakan and Shah Alam were implementing the guideline in their territory for new housing developments. Effort of Majlis Bandaraya Shah Alam (MBSA) was implementing in Kota Damansara's new housing project and nearly 40% of the rainwater harvesting system installed has been dismantled to give way for renovation. Based on statistics of the level of installation in Malaysia, rainwater harvesting is difficult to implement due to the unfriendly design which had taken too much space in the backyard, expensive to begin installation the components, due to the concern of mosquito breeding and it is not mandatory (Mohd. Shahwahid et a.l, 2007).

Difficulties to implement rainwater can be overcome as the Ministry had introduced rating and award for those who implement rainwater harvesting which is the Green Building Index (GBI) (Mohd. Shahwahid, et al., 2007). This may also act as an added value to the property for being energy efficient. On the design issues, perhaps Malaysian architects and engineers should work together to come up with good design that can prevent mosquito breeding and more environmental and space-friendly. Malaysia can make New South Wales, Australia as a role model because their local governments have introduced the Basic Sustainability Index or BASIX to rate environmentally sustainable buildings.

Based on facts and statements above rainwater harvesting is a traditional system that was pass through out innovation and improvement to overcome water crisis with simple technology but give a large impact.

2.3 RAINWATER HARVESTING TECHNIQUE

Rainwater harvesting has a long tradition for a long of years. It is a technology used for collecting and storing rainwater from roof surface, land surfaces or rock catchments with a simple technique such as natural and artificial ponds and tanks. One millimetre of harvested rainwater is equivalent to one litre water per square metre. Harvested rainwater can be source in households for drinking, cooking, sanitation, as well as for productive use in agriculture and landscape watering (Helmreich & Horn, 2008).

There are three major forms of rainwater harvesting (Helmreich & Horn, 2008):

1. In-situ rainwater harvesting by collecting rainwater on surface where if falls and storing in the soil and usually for agricultural and landscape watering.
2. External rainwater harvesting by collecting runoff originating from over a surface and stored offside and landscape watering.
3. Domestic rainwater harvesting, where water is collected from roofs and street and courtyard drainage.

Rainwater harvesting is the traditional technique with Morden innovation by collecting and storage of rainwater from gutter during rain for future purpose and this technique were implement in many countries like United Kingdom, Germany, China, Japan, Thailand, Sri Lanka, India, Australia, Brazil and United States of America. For areas with sufficient rainfall for collection but experiencing water shortage due to either limited availability of conventional water resources or due high water demand. It can also be used in arid regions to overcome water shortage is relevant to implement this technique. Rainwater harvesting technique can be separate into two parts which are portable and non-portable (Mohammed, Mohd. Noor & Ghazali, 2008). Portable rainwater harvesting for domestic purpose are drinking, bathing, cooking, washing and etc. and for non-portable rainwater harvesting are flushing toilet, watering garden and etc. rainwater harvesting need to pass through treatment process before in can be used for drinking water.

Components of rainwater harvesting are very simple that drainage form rooftop and connected to storage tank. Rooftop as a medium collector in rainwater harvesting system will gather water from rainfall and flow through drainage before store in a storage tank. There are various types and materials of construction method for roof such as concrete slab, plastic corrugated sheets, metal corrugated sheets, corrugated cement tiles and corrugated clay tiles. Every building had a difference size of catchment for rainwater collection. The volume of rainwater collected influence by the size of catchment and intensity of the rainfall. Thus, small roof size or catchment usually found in residential building and large size is found in super markets, warehouse and airports.

The reliability of rainwater harvesting systems mainly depends on collected rainwater volume and related to the nature of water consumption for potable and non-potable uses. Most rainwater harvesting systems were installed in many countries including Malaysia but the concerns about the reliability of these systems are weak. Shaaban et al. (2002) tested the usage of rainwater harvesting installed in a house located in Kuala Lumpur, Malaysia and according to the experiment done he recommended to use the rainwater mainly for washing clothes and flushing toilets. Ruslan (2003) proposed computer software for determining the reliability of rainwater tank. Also Ghisi and Ferreira (2006) studied the reliability of rainwater harvesting for 26 cities in Brazil. Gould and Nissen-Peterson (1999) gave the runoff coefficients for various materials used for roofing. Rahman and Fatima (2006) and Handia et al. (2003) reviewed the materials of rainwater storage tank

2.3.1 Agricultural Rainwater Harvesting

Irrigation of plants by using of rainwater harvesting is a wise option to maximizing productivity of water usage and therefore plantation yields can be increase. Rainfed agriculture in arid and semi-arid areas contributes to up to 90% of the total cereal production of these regions (Helmreich & Horn, 2008). However, in many countries, productivity remains low due to less than optimal rainfall characteristics, unfavourable land conditions and lack of proper management of these resources. Increasing productivity of rain fed areas could increase food security, improve livelihoods, and reduce irrigation frequency. Apart from the climate, the landscape must be suited for rainwater agriculture. Following minimal requirements have to be fulfilled (Helmreich & Horn, 2008).

1. The landscape surface must be such that runoff is readily generated by rainfall.
2. Differences in elevation must be present in the landscape surface. The runoff generated by rainfall must be allowed to flow and to be concentrated in the specially prepared parts of the landscape.
3. The runoff receiving part must have sufficiently deep soils of suitable texture and structure to retain and store the received runoff water. Storage can be achieved by various types of surface and sub-surface storage systems. The method of application differs according to the financial strength. Runoff collection may involve land alterations, soil compaction, etc., to increase the runoff from the catchment areas.
4. Micro-catchment systems: They constitute specially contoured areas with slopes and berms designed to increase runoff from rain and concentrate it in a planting basin where it infiltrates the soil profile and is effectively "stored" therein. The water is available for plants but protected from evaporation. Micro catchments are simple and inexpensive and can be rapidly installed using local materials and manpower. There are three types of micro-catchments: contour bench terraces, runoff strips, and micro-watersheds.

5. Sub-surface dams, sand dams or check dams: Water is stored underground in an artificially raised water table or local sub-surface reservoir.
6. Tanks of various forms made of plastic, cement, clay, soil, etc.: They can be built underground or above ground, depending on space, technology and investment capacity.

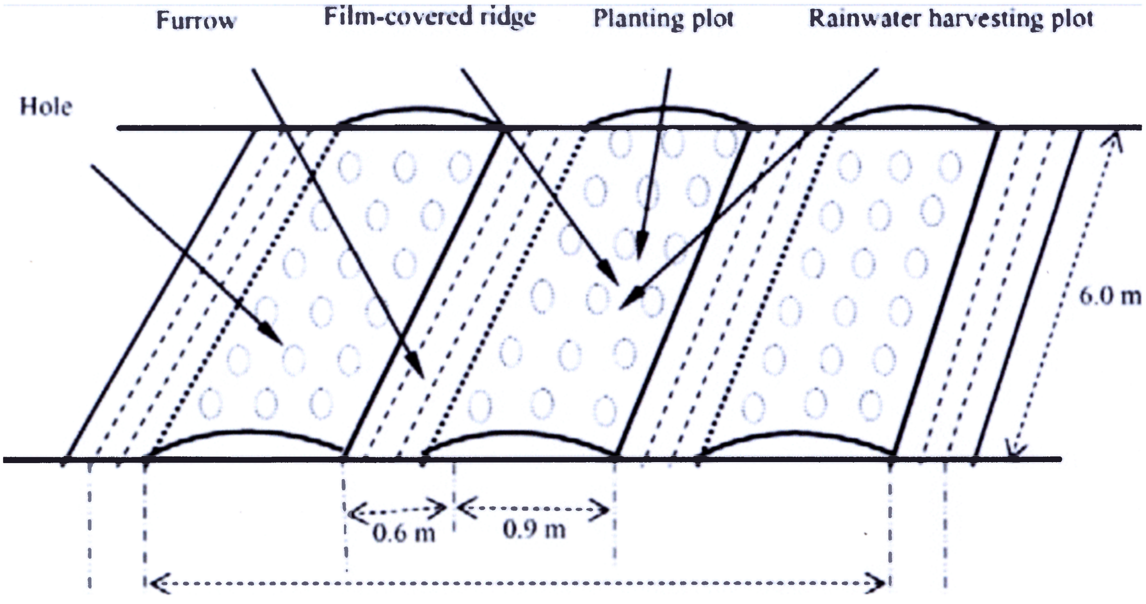


Figure 2.1: shows an example for field cultivation of RWH in a micro-catchment (Source from Helmreich & Horn, 2008).

2.3.2 Domestic Rainwater Harvesting

For domestic rainwater harvesting, rainwater is collected from rooftops, courtyards and can be stored close to these. The storage tanks can be built underground or aboveground. The storage size depends on the requirements. Usually tank shapes are cuboid, cylindrical or doubly curved. For storage smaller storage tanks made of bricks, stabilized soil, rammed earth, plastic sheets and mortar jars are common. For larger quantities rainfall water containers can be made of pottery, Ferro cement, or polyethylene. The polyethylene tanks are compact but have a large storage capacity.

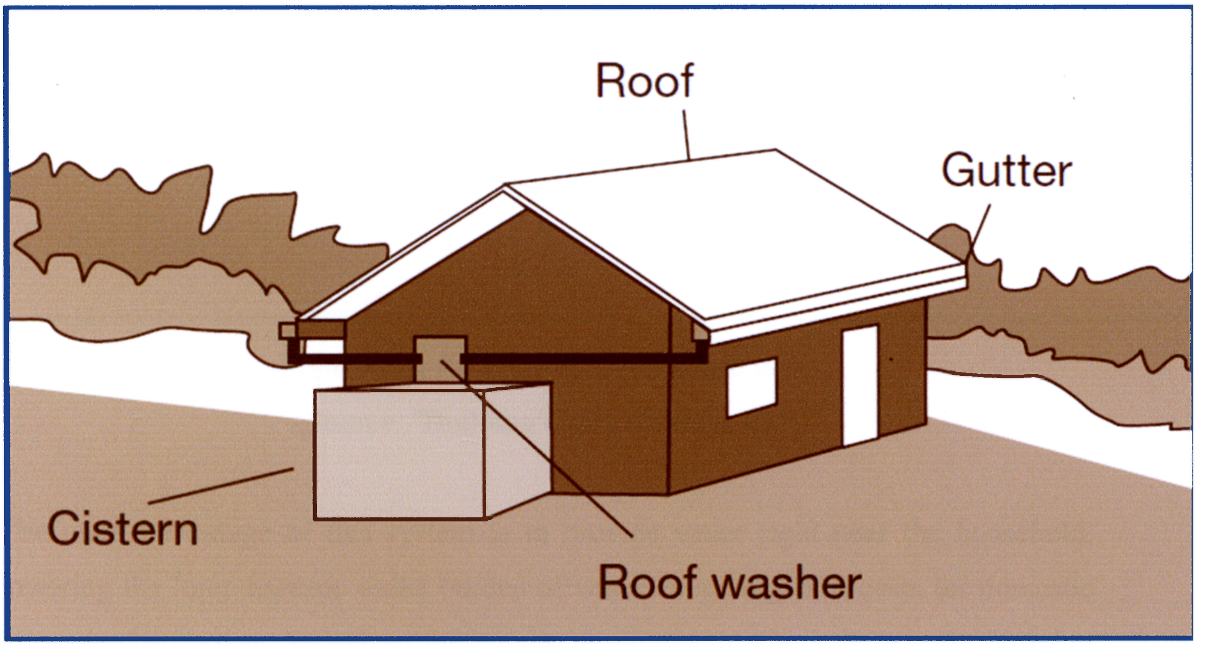


Figure 2.2: A simple rainwater harvesting design with an external storage tank.
(Source: "Building codes division, nd")

The rainwater may be stored in underground tanks or above ground tanks. Precautions required in the use of storage tanks include provision of an adequate enclosure to minimise contamination from human, animal or other environmental contaminants, and a tight cover to prevent algal growth and breeding of mosquitoes. Open containers are not recommended for collecting water for drinking purposes. The stored water is used for domestic purposes, garden watering and small scale productive activities.

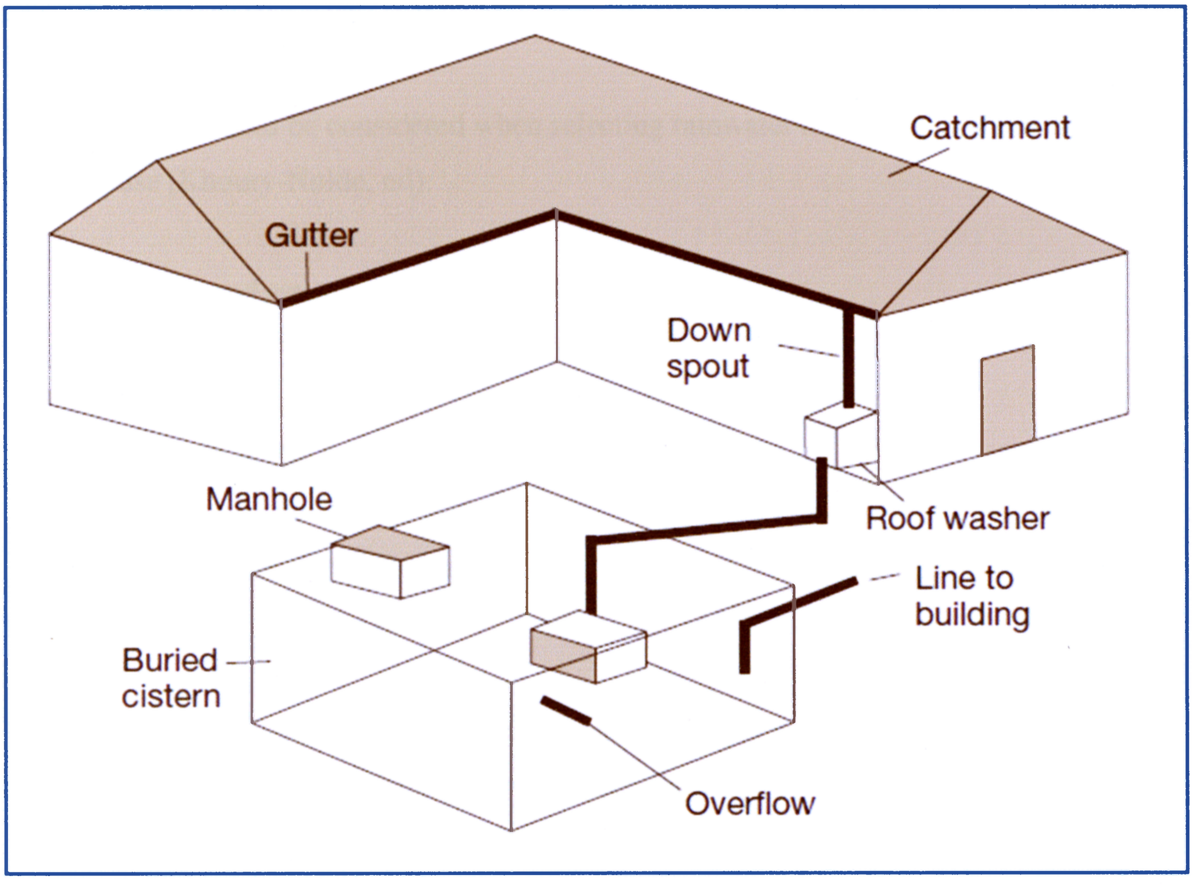


Figure 2.3: An underground storage tank.

(Source: "Building codes division, nd")

The main advantage of this system is to provide water right near the household, lowering the long distance walks burden of water collecting. The costs for domestic rainwater harvesting depend on the on-site requirements. Capital costs are high but neither operation nor maintenance usually involves significant expenditure. The benefit of a tank is not strictly proportional to its size. The reason is that a smaller tank will be filled and emptied often whereas a larger tank will only be cycled rarely.

2.4 CRITERIA FOR SELECTION OF RAINWATER HARVESTING

Several factors should be considered when selecting rainwater harvesting systems for domestic use (Khoury-Nolde, nd):

1. Type and size of catchment area
2. Local rainfall data and weather patterns
3. Family size
4. Length of the drought period
5. Alternative water sources
6. Cost of the rainwater harvesting system.

When rainwater harvesting is mainly considered for irrigation, several factors should be taken into consideration. These include (Khoury-Nolde, nd):

1. Rainfall amounts, intensities, and evaporate-transpiration rates
2. Soil infiltration rate, water holding capacity, fertility and depth of soil
3. Crop characteristics such as water requirement and length of growing period
4. Hydrogeology of the site.
5. Socio-economic factors such as population density, labour, costs of materials and regulations governing water resources use.

2.5 METHOD OF RAINWATER COLLECTION

Although rainwater can be harvested from many surfaces, rooftop harvesting systems are most commonly used as the quality of harvested rainwater is usually clean following proper installation and maintenance. The effective size of roof and the material used in constructing the roof gave large influence on efficiency of collection and the water quality.

Rainwater harvesting systems generally consist of four basic elements:

1. a collection (catchment) area
2. a conveyance system consisting of pipes and gutters
3. a storage facility, and
4. A delivery system.

The elements of rainwater harvesting system should be maintained in good and clean (free of debris) condition in order to reduce contamination in rainwater. Contamination of water might arise from the roofing material itself or from substances such as dust and bird droppings that have blown or fallen onto a roof or into a gutter (Mosley, 2005).

2.5.1 Collection or Catchment System

Catchment area is the surface area from which rainwater can be collected as clean water. Usually, this comprises the roof over a house, and any associated covered portions of the dwelling, including sheds, factory roofs, or etc. that is situated above ground level (Jitender Dev Sehgal, 2005-2006). The collected rainwater can be for irrigation or washing vehicle immediately after collected, however if the rainwater is collected for drinking purpose, only the rainwater that is collected from rooftop with the suitable material is suggested to be collected . In addition some treatment on the rainwater should be carried out to eliminate the contaminants.

The quantity of water available from a rainwater harvesting system depends on the size of the catchment surface, the percentage catchment surface area that is guttered, the efficiency of the gutters in transporting the water, and the size of the storage tank. Furthermore, the rainfall pattern and user-demand are also factors that must be taken into account. Rainwater yield varies with the size and texture of the catchment area. A smoother, cleaner, and more impervious roofing material contributes to better water quality and greater quantity.

The catchment surfaces must be made of non-toxic material and painted surfaces should be avoided if possible, or if the use of paint is necessary, only non-toxic paint shall be used such as the paint that no lead-based, chromium-based, or zinc-based paint. Other material options such as clay tile or slate are appropriate for rainwater intended to be used as potable water. These surfaces can be treated with a special painted coating to discourage bacterial growth on an otherwise porous surface. The use of composite asphalt, asbestos, chemically treated wood shingles and some painted roofs could leach toxic materials into the rainwater as it touches the roof surface. They are recommended only for non-potable water uses, (Texas Water Development Board, 1997).

Rainwater also can be harvested using ground or land surface catchment area which this method is less complex. It involves improving runoff capacity of the land surface through various techniques including collection of runoff with drain pipes and storage of collected water. There is a possibility of high rates of water loss due to infiltration into the ground, and, because of the often marginal quality of the water collected, this technique is mainly suitable for storing water for agricultural purposes (Department of Irrigation & Drainage, 2008).

Figure 2.4: Catchment area of rainwater harvesting system.

2.5.2 Conveyance System

A conveyance system is required to transfer the rainwater from the roof catchment area to the storage system by connecting roof drains (drain pipes) and piping from the roof top to one or more that transport the rainwater through a filter system to the storage tanks. Materials suitable for the pipework include polyethylene (PE), polypropylene (PP) or stainless steel. PE drains are recommended as they do not rust so water quality will be maintained over a long period of time. Before water is stored in a storage tank or cistern, and prior to use, it should be filtered to remove particles and debris. The choice of the filtering system depends on the construction conditions. The correct installation of drains is most important so that there are no flat areas where debris and water may pool, as these may provide sites for mosquitoes to breed. If a large amount of leaf material is present and it is not desirable to remove an overhanging tree, drains screens may also be used. Low-maintenance filters with a good filter output and high water flow should be preferred. "First flush" systems which filter out the first rain and diverts it away from the storage tank should be also installed. This will remove the contaminants in rainwater which are highest in the first rain shower (Khoury-Nolde, nd).

2.5.3 Storage Tank or Cistern

Storage tank or cistern to store harvested rainwater for use when needed. Depending on the space available these tanks can be constructed above grade, partly underground, or below grade. They may be constructed as part of the building, or may be built as a separate unit located some distance away from the building.

The storage tank should be also constructed of an inert material such as reinforced concrete, Ferro cement (reinforced steel and concrete), fibreglass, polyethylene, or stainless steel, or they could be made of wood, metal, or earth. The choice of material depends on local availability and affordability. Various types can be used including cylindrical Ferro cement tanks, mortar jars (large jar shaped vessels constructed from wire reinforced mortar) and single and battery (interconnected) tanks. Polyethylene tanks are the most common and easiest to clean and connect to the piping system. Storage tanks must be opaque to inhibit algal growth and should be located near to the supply and demand points to reduce the distance water is conveyed (Khoury-Nolde, nd).

Water flow into the storage tank or cistern is also decisive for the quality of the cistern water. Calm rainwater inlet will prevent the stirring up of the sediment. Upon leaving the cistern, the stored water is extracted from the cleanest part of the tank, just below the surface of the water, using a floating extraction filter. A sloping overflow trap is necessary to drain away any floating matter and to protect from sewer gases. Storage tanks should be also kept closed to prevent the entry of insects and other animals.

2.5.4 Delivery System

Delivery system which delivers rainwater and it usually includes a small pump, a pressure tank and a tap, if delivery by means of simple gravity on site is not feasible. Disinfection of the harvested rainwater, which includes filtration and/or ozone or UV disinfection, is necessary if rainwater is to be used as a potable water source. The delivery system will distribute rainwater into house or tank before used.

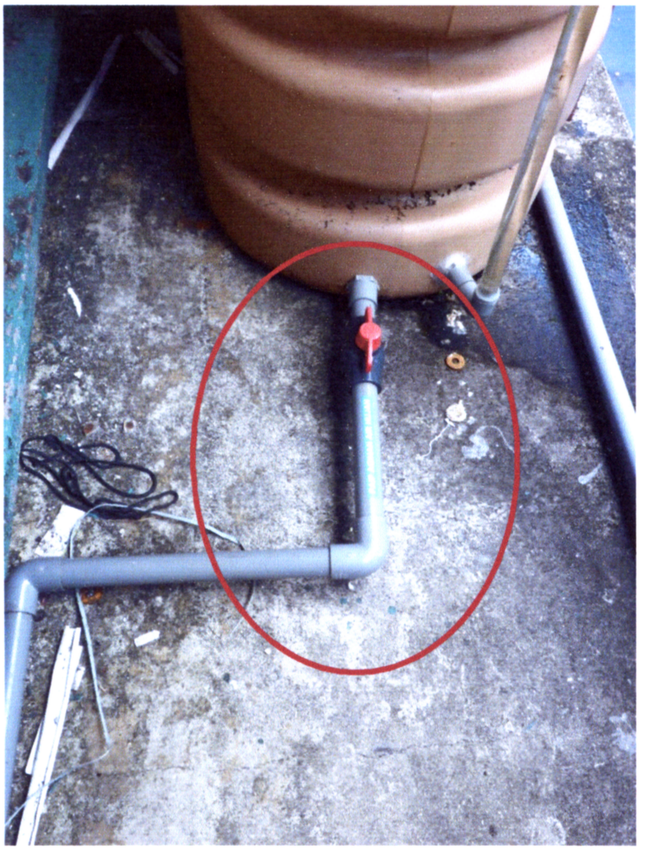


Figure 2.5: Delivery pipe of harvested rainwater for domestic purpose or agriculture purpose.

2.6 RAINWATER HARVESTING EFFICIENCY

The efficiency of rainwater harvesting depends on the materials used, design and construction, maintenance and the total amount of rainfall. A commonly used efficiency figure, runoff coefficient, which is the percentage of precipitation that appears as runoff, is 0.8 (Khoury-Nolde, nd).

For comparison, if cement tiles are used as a roofing material, the year-round roof runoff coefficient is about 75%, whereas clay tiles collect usually less than 50% depending on the harvesting technology. Plastic and metal sheets are best with an efficiency of 80-90% (Khoury-Nolde, nd).

For effective operation of a rainwater harvesting system, a well-designed and carefully constructed gutter system is also crucial. 90% or more of the rainwater collected on the roof will be drained to the storage tank if the gutter and down-pipe system is properly fitted and maintained. Common materials for gutters and down-pipes are metal and plastic, but also cement-based products, bamboo and wood can be used (Khoury-Nolde, nd).

2.7 QUALITY OF HARVESTED RAINWATER

Pure rainwater is mostly low polluted depending on the quality of the atmosphere. Atmospheric pollutants including particles, microorganisms, heavy metals and organic substances, accumulate on the catchment areas as dry deposition and are washed out from the atmosphere during rainfall events. Rainwater in rural areas being situated far from atmospheric and industrial pollution is fairly clean except for some dissolved gases. On the other hand urban areas are characterized by a high traffic and industry impact. therefore rainwater possibly contaminated by particles, heavy metals and organic air pollutants (Helmreich & Horn, 2008).

In addition, the catchment surfaces themselves may be a source of heavy metals and organic substances. Low or not polluted rainwater can be collected from roofs constructed with tiles, slates and aluminium sheets. Roof tied with bamboo gutters are least suitable because of possible health hazards. Similarly, zinc and copper roofs or else roofs with metallic paint or other coatings are not recommended because of high heavy metal concentrations. It was found that the measured inorganic compounds in the rainwater harvested from most roof yard catchment systems generally matched the World Health Organization (WHO) standards for drinking water, while the concentrations of some inorganic compounds in the rainwater collected from road surfaces appeared to be higher than the guideline values for drinking water, but generally not beyond the maximum permissible concentrations. If the catchment areas are roads the rainwater maybe polluted by heavy metals originating from brakes and tires, and by organic compounds like polycyclic aromatic hydrocarbons (PAH) and aliphatic hydrocarbons from incomplete combustion processes (Helmreich & Horn, 2008).

To apply drinking water quality the removal of these hazardous compounds is necessary. Bacteria, viruses and protozoa may originate from faecal pollution by birds, mammals and reptiles that have access to catchments and rainwater storage tanks. The presence of microbial indicators and pathogens has been found to vary greatly with reported counts up to thousands CFU/100 mL. Sazakli et al., nd analysed three widely used bacterial indicators. They found coliforms in 80.3% of rainwater samples, Escherichia coli and enterococci in 40.9% and 28.8%, respectively (Helmreich & Horn, 2008). Therefore, harvested rainwater is often unsuitable for drinking without any treatment. Disinfection should then be applied to improve microbiological quality.

2.8 DEVICES & TECHNIQUES THAT FURTHER AID IN BETTER WATER QUALITY

2.8.1 First Flush and Filter Screens

The first rain drains the dust, bird droppings, leaves, etc. which are found on the roof surface. To prevent these pollutants from entering the storage tank, the first rainwater containing the debris should be diverted or flushed. Automatic devices that prevent the first 20-25 litres of runoff from being collected in the storage tank are recommended (Khoury-Nolde, nd).

Screens to retain larger debris such as leaves can be installed in the down-pipe or at the tank inlet. The same applies to the collection of rain runoff from a hard ground surface. In this case, simple gravel-sand filters can be installed at the entrance of the storage tank to filter the first rain.

Filtration Screens

The quality of stored water can be much improved if leaves and other debris are kept out of the system by the use of a coarse filter or screen. Without screens present, leaves and other material may enter tanks and provide food and nutrients for micro-organisms to survive. In the absence of such nutrients, bacteria eventually (2-20 days) die off from starvation (Mosley, 2005). A filter or screen should be durable, easy to clean and replace, and should not block. It is essential that there are no gaps in the storage tank inlets where mosquitoes can enter or exit.

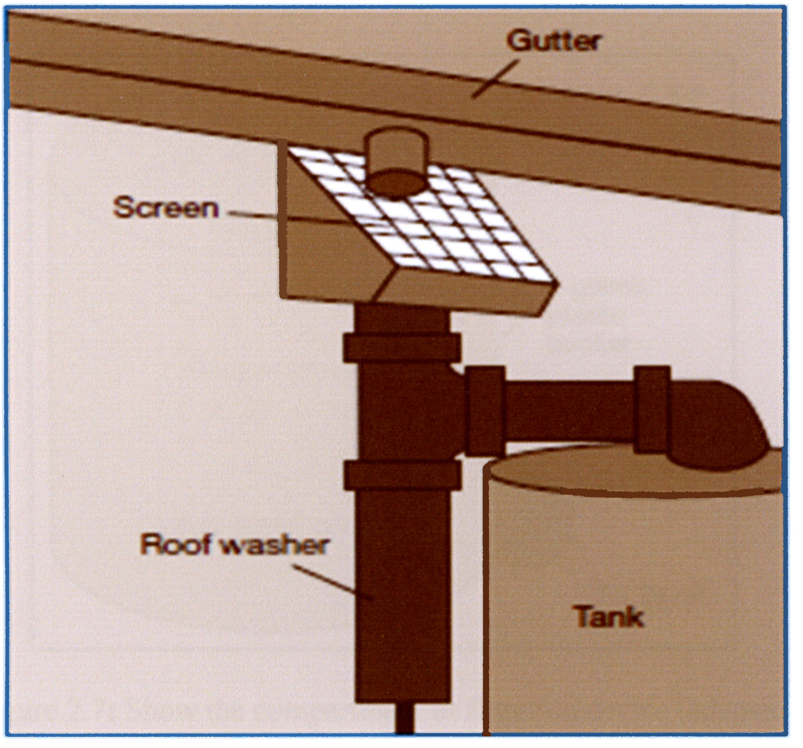


Figure 2.6: A leaf screen (filtration) at the downspout and a first flush diverter (adapted from "Building codes division, nd").

Coarse filtration screens (made of stainless steel or synthetic mesh) are the simplest, most inexpensive and widely used technology. Typically these are mounted across the top inlet of the storage tank with the downpipe above the screen. Alternatively, the downpipe from the roof could enter the tank through an appropriately sized hole at the top of the tank with the filtration screen at the entrance to the downpipe from the gutter. Coarse filter screens are recommended for all tanks in the Pacific Islands as an economical way to provide some basic water quality improvement. Finer filter devices have been used to remove small sized sediment which would otherwise either be suspended in the water or settle to the bottom of the tank leaving sludge. These also effectively remove bacteria (Faisst and Fujioka 1994).

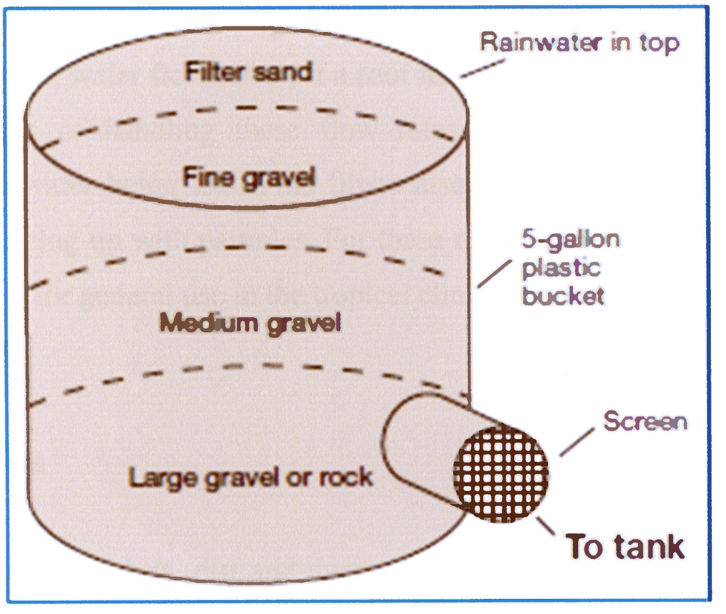


Figure 2.7: Show the compartment of filtration device (adapted from "Building codes division, nd")

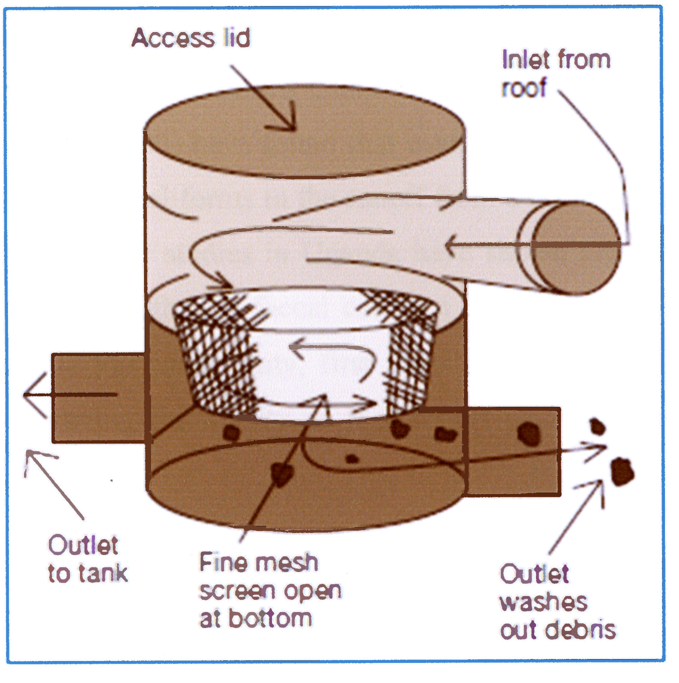


Figure 2.8: Other types of filtration of RWH (adapted from "Building codes division, nd")

The devices usually used are gravel, sand or fine filter screens. However, in a tropical rain shower, water flow rates off a roof may be very high and fine filters are often not capable of handling these flow rates without resulting in the filter overflowing and water being lost. Fine filters also require regular cleaning due to their tendency to clog up with particles. For these reasons fine filtration systems are not recommended for general use in the tropical climate country (Macomber, 2001).

First-flush devices

Contaminants such as debris, dirt and dust collect on roofs during dry periods and during the initial period of rainfall this material is washed into the storage vessel. Following this initial 'first flush' of contaminants the water collected is much cleaner and safer to drink (Otieno 1994). First flush water separating systems dispose of the 'first flush' water so that it does not enter the storage tank. The amount of first flush water that needs to be removed before water is safe to drink has been found to vary between different studies. Yaziz et al. (1989) found that 0.5 mm of rain was sufficient to reduce the faecal coliforms count to zero on two roofs in a Malaysian campus. Coombes et. al (2000) have found that even after 2 mm was flushed, there were still significant faecal coliforms in the runoff from a building located close to a bus depot in Australia. Field studies in Uganda have shown unacceptable turbidity after 2 mm have removed although faecal coliform counts were in the WHO "low risk" category. Despite this uncertainty, first flush systems are considered a very good method of improving the quality of roof runoff prior to storage (Faisst and Fujioka 1993).

2.9 TYPES OF CONTAMINANTS IN RAINWATER TANK SYSTEMS

The types of contaminants commonly found in rainwater collection systems are listed below:

Contaminant	**Source**	**Risk of entering Rain Tank**
Dust and Ash	Surrounding dirt and vegetation Volcanic activity	Moderate: Can be minimized by regular roof and gutter maintenance and use of a first-flush device
Pathogenic Bacteria	Bird and other animal droppings on roof, attached to dust	Moderate: Bacteria may be attached to dust or in animal droppings falling on the roof. Can be minimized by use of a firstflush device and good roof and tank maintenance.
Heavy metals	Dust, particularly in urban and industiralised areas, roof materials	Low: Unless downwind of industrial activity such as a metal smelter and/or rainfall is very acidic (this may occur in volcanic islands)
Other Inorganic Contaminants (e.g. salt from seaspray)	Seaspray, certain industrial discharges to air, use of unsuitable tank and/or roof materials	Low: Unless very close to the ocean or downwind of large scale industrial activity
Mosquito Larvae	Mosquitos laying eggs in guttering and/or tank	Moderate: If tank inlet is screened and there are no gaps, risks can be minimized.

Table 2.1: contaminant in RWH system (adapated from "Building codes division, nd")

2.10 FACTOR INFLUENCE RAINWATER HARVESTING

Styles of RWH – system, climate and geographical variables

Rainwater that has been harvested is used in many different ways. In some parts of the world it is used merely to capture enough water during a storm to save a trip or two to the main water source. Here, only small storage capacity is required, maybe just a few small pots to store enough water for a day or half a day. At the other end of the spectrum we see, in arid areas of the world, systems which have sufficient collection surface area and storage capacity to provide enough water to meet the full needs of the user. Between these two extremes exists a wide variety of different user patterns or regimes. There are many variables that determine these patterns of usage for RWH. Some of these are listed below (Rainwater harvesting, nd):

1. Rainfall quantity (mm/year)
2. Rainfall pattern - The type of rainfall pattern, as well as the total rainfall, which prevails will often determine the feasibility of a RWHS. A climate where rain falls regularly throughout the year will mean that the storage requirement is low and hence the system cost will be correspondingly low and vice versa. More detailed rainfall data is required to ascertain the rainfall pattern. The more detailed the data available, the more accurately the system parameters can be defined.
3. Collection surface area (m^2)
4. Available storage capacity (m^3)
5. Daily consumption rate (litres/capita /day or lpcd) - this varies enormously – from 10 – 15 lpcd a day in some parts of Africa to several hundred lpcd in some industrialised countries. This will have obvious impacts on system specification.
6. Number of users - again this will greatly influence the requirements.
7. Cost – a major factor in any scheme.

8. Alternative water sources – where alternative water sources are available, this can make a significant difference to the usage pattern. If there is a groundwater source within walking distance of the dwelling (say within a kilometre or so), then a RWHS that can provide a reliable supply of water at the homestead for the majority of the year, will have a significant impact to lifestyle of the user. Obviously, the user will still have to cart water for the remainder of the year, but for the months when water is available at the dwelling there is a great saving in time and energy. Another possible scenario is where rainwater is stored and used only for drinking and cooking, the higher quality water demands, and a poorer quality water source, which may be near the dwelling, is used for other activities.
9. Water management strategy – whatever the conditions, a careful water management strategy is always a prudent measure. In situations where there is a strong reliance on stored rainwater, there is a need to control or manage the amount of water being used so that it does not dry up before expected.

As simply classify most systems by the amount of 'water security' or 'reliability' afforded by the system. There are four types of user regimes listed below:

Occasional - water is collected occasionally with a small storage capacity, which allows the user to store enough water for a maximum of, say, one or two days. This type of system is ideally suited to a climate where there is a uniform, or bimodal, rainfall pattern with very few dry days during the year and where an alternative water source is available nearby.

Intermittent – this type of pattern is one where the requirements of the user are met for a part of the year. A typical scenario is where there is a single long rainy season and, during this time, most or all of the users' needs are met. During the dry season, an alternative water source has to be used or, as we see in the Sri Lankan case, water is carted/ bowered in from a nearby river and stored in the RWH tank. Usually, a small or medium size storage vessel is required to bridge the days when there is no rain.

Partial – this type of pattern provides for partial coverage of the water requirements of the user during the whole of the year. An example of this type of system would be where a family gather rainwater to meet only the high-quality needs, such as drinking or cooking, while other needs, such as bathing and clothes washing, are met by a water source with a lower quality.

Full – with this type of system the total water demand of the user is met for the whole of the year by rainwater only. This is sometimes the only option available in areas where other sources are unavailable. A careful feasibility study must be carried out before hand to ensure that conditions are suitable. A strict water management strategy is required when such a system is used to ensure that the water is used carefully and will last until the following wet season.

2.11 PROBLEMS AND CONSTRAINTS OF RAINWATER HARVESTING

Even though rainwater harvesting is a helpful technique for areas with scarce water resources there are some problems hindering the integration and implementation. Often the technology used is inadequate to meet the requirements of the region or else is too expensive. Sometimes there is a lack of acceptance, motivation and involvement among users. Hydrological data and information for confident planning, design and implementation of rainwater harvesting systems are missing. Additionally there is often an insufficient attention to social and economic aspects such as land tenure and unemployment. Often the people's knowledge with regard to rainwater harvesting and use is inadequate and outdate giving away the benefits of rainwater resources. Absence of long-term government strategies is also a handicap. In some regions domestic rainwater harvesting is in fact illegal if water legislation is strictly applied. Therefore a lot of development work has to be done in this matter. Geographic information systems (GIS)-based models, which combine physical, ecological and socio-economic data, might contribute to assess the suitability of a given area to rainwater harvesting.

2.12 ADVANTAGE OF RAINWATER HARVESTING

Rainwater harvesting in urban and rural areas offers several benefits including provision of supplemental water, increasing soil moisture levels for urban greenery, increasing the groundwater table via artificial recharge, mitigating urban flooding and improving the quality of groundwater. In homes and buildings, collected rainwater can be used for irrigation, toilet flushing and laundry. With proper filtration and treatment, harvested rainwater can also be used for showering, bathing, or drinking. The major benefits of rainwater harvesting are summarised below (Khoury-Nolde, nd):

1. Rainwater is a relatively clean and free source of water
2. Rainwater harvesting provides a source of water at the point where it is needed
3. It is owner-operated and managed
4. It is socially acceptable and environmentally responsible
5. It promotes self-sufficiency and conserves water resources
6. Rainwater is friendly to landscape plants and gardens
7. It reduces storm water runoff and non-point source pollution
8. It uses simple, flexible technologies that are easy to maintain
9. Offers potential cost savings especially with rising water costs
10. Provides safe water for human consumption after proper treatment
11. Low running costs
12. Construction, operation and maintenance are not labour-intensive.

2.12 DISADVANTAGES OF RAINWATER HARVESTING

The main disadvantages of rainwater harvesting technologies are the limited supply and uncertainty of rainfall. Rainwater is not a reliable water source in times of dry periods or prolonged drought. Other disadvantages include (Khoury-Nolde, nd):

1. Low storage capacity which will limit rainwater harvesting, whereas, increasing the storage capacity will add to the construction and operating costs making the technology less economically feasible.
2. possible contamination of the rainwater with animal wastes and organic matter which may result in health risks if rainwater is not treated prior to consumption as a drinking water source
3. leakage from cisterns can cause the deterioration of load-bearing slopes
4. Cisterns and storage tanks can be unsafe for small children if proper access protection is not provided.

CHAPTER 3

CHAPTER 3

RESEARCH METHODOLOGY

3.0 INTRODUCTION

This chapter elaborates on the methods and procedures in carrying out this study. The research methodology consist of five stages; identification of issues and limitation of research, data collection, case studies, analysis, conclusion and finally recommendation.

3.1 TYPES OF DATA COLLECTION

The first step of the study was to identify the research problem which covered the significance, objective and the scope of the study followed by exploratory research of the literature. For the purpose of this study, the research methodology is literature review, collect data, analysis data and report on findings and conclusions. The information needed for this research was obtained from literature reviews and interview survey. There are two (2) types of data which is primary and secondary data. It is essential to describe the methodologies to ensure all the data and information gathered is reliable and to show that it is systematically collected and analyses.

RESEARCH CHART

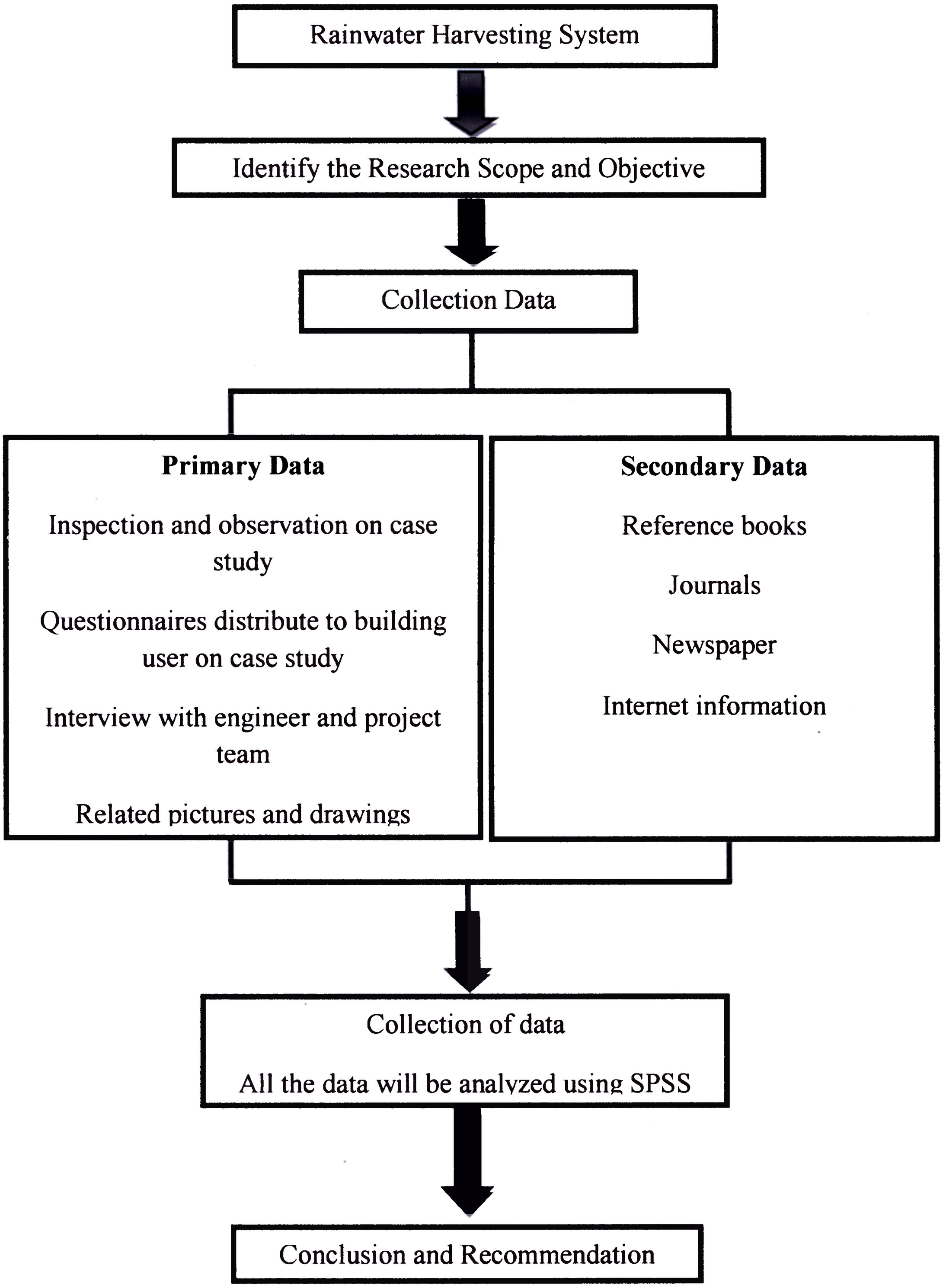


Figure 3.1: Flowchart of Methodology Study

3.2 METHOD PREPARATION OF DATA COLLECTION

3.2.1 Identification of Problem

Identify of problems, barriers or any inadequacy that associated with rainwater harvesting in Klang Valley. The objectives of the study at the same time were established. The data to address objective shall be collected via primary and secondary data. The case study involves on Green Building and housing development that implement rainwater harvesting system in Klang Valley.

3.2.2 Literature Review

The purpose of conducting the literature review is to enhance the knowledge and understanding of this study. By literature reviews, the outline and overview of the research topic can be identified. Besides that, necessary information and additional references needed for this study can be gained by conducting literature reviews. The materials for literature reviews are such as books, articles, magazines, internet, journals, documents and etc. The literature review thus provides guidance towards the preparation of the survey interview, which is discussed in the following section.

3.2.3 Data Collection

The sources of data are clarified into two sources which are primary data sources and secondary data sources. In this study both primary and secondary data have been used in order to get sources of data.

3.2.3.1 Primary data

According to Uma Sekaran (2000), primary data is information that first obtained by the researcher on the variables of interest for the specific purpose of study. On the other hand, primary data is defined as a data originated by the researcher specifically to address the research problem (Malhotra, 2010). To obtain information, a set of questionnaire is distributed to rainwater harvesting user. The quantitative research was used in this study. The quantitative research seeks to quantify the data and, typically, applies some form of statistical analysis (Malhotra, 2010).

Primary data is the data observed and collected directly from the first-hand experience or the data is derived from a new or original research study and collected at the sources. In this study, the research instrument used to obtain primary data is the questionnaire.

3.2.3.1 Secondary Data

According to Malhotra (2010), secondary data are data collected for some purpose other than the problem at hand. Secondary data also refer to the information gathered by someone than the researcher conducting the current study such as company record, publication, industry analysis offered by the media, web publications and so on (Uma Sekaran, 2000). It is less time consuming and cheap to obtain the secondary data as it is already prepared by other experts. The secondary data is to get more information that could support the primary data, strengthen the information and also assist the researcher to interpret the primary data correctly. At times, secondary data can also give an insight to the researcher on the subject matters from difference perspective (Malhotra, 2010).

Secondary data is the data that have been already collected by and readily available from other sources. It used to strengthen the description and explanation is made as the basis for this study. For this purpose of study, the information have been gathered by the databases, articles, journals, article, reports and book from the university library which are relevant able to support the literature review.

3.2.4 Semi-structured Interview

Interviews are another technique to collect factual information as well as opinion. It's are an efficient method to collect data as the reality of a situation can be observed in detail and thoroughly during the interview sessions. Researcher can have chances directly with respondents to get relevant information

3.2.5 Questionnaire

This is a descriptive study using statistical data to generate result. In this study, data was collected using a structured questionnaire where questionnaire was distributed to rainwater harvesting user at Klang Valley, in order to assess result about knowledge of rainwater harvesting, benefits of rainwater harvesting and problems and barriers of rainwater harvesting system.

To gain the data information for this method for this study is by using the questionnaires. The research questionnaire will be filled up by occupants of building in three case studies and approximate target respondents is 20% from occupants of building. The first part consists of demographic information of the subject, such as gender, age, occupation, education level, and knowledge about rainwater harvesting system. The second part was designed for the collection of data about the independent variable such as benefits of rainwater harvesting system. Last but not least part is the independent variable which is problems and barriers of rainwater harvesting.

The Likert scale, an interval scale, which requires the respondents to indicate their levels of agreement and disagreement by placing a "X" or a tick at the appropriate number in the corresponding boxes. The Likert-scale was used for the collection of data for all both part two and part three. Likert scale is basically a 5-point scale (Strongly Agree = 5, Agree = 4, Neutral = 3, Disagree = 2, strongly Disagree= 1) which consists of values from 5 to 1. (Likert, 1932).

3.2.6 Case Study

The case study for this research will focus on on Green Building in Klang Valley. Site visits to case study areas will be conducted in order to gather information through observation and professional buildings manager or project manager have assisted in this study. During this stage, interview process was carried out to elicit the information and opinions related to rainwater harvesting system which has been practiced before. The target of participants for the interview is the engineer, the project manager, the technician assistant and user.

Unstructured interviews have been used in this research to gain a general understanding of the requirements and the system used on the building from the professionals' on the implementation of rainwater harvesting on green building in Malaysia. An informal discussion with the professionals' building has been done by allowing the discussion to be open. The reasons unstructured interviews was chosen for this research is because unstructured interview are flexible, simple, informal and time saving when preparing for the interview. In addition, unstructured interviews allow spontaneity to the interviews. Interviewer also has the freedom to change some questions or the sequence of the questions according to the responses or reactions from the interviewees when having the face-to-face discussions.

3.3 DATA ANALYSIS TECHNIQUES

After collecting the information from the questionnaires, a few procedures will be done such as checking the data for accuracy. Besides that the questions were being coded to enable for analysis using Statistical Packages for the Social Science (SPSS) which is PC version 19.

3.3.1 Reliability Test (Cronbach's Alpha Test)

The analysis of data begins with reliability test which is Cronbach's Alpha Test. Reliability refers to the extent to which scale produces consistent results if repeated measurements are made on the characteristics (Hong, 2007). This reliability test measures the internal consistency and stability of the multi-item scales (Hong, 2007). According to Sekaran (2003), the reliability of a measure indicates the extent to which it is without bias (error free) and hence ensures consistent measurement across time and across the various items in the instrument.

The Cronbach's alpha measures the internal consistency or homogeneity among the multi-item scales such as the interval level measurement. Its coefficient measures how well the items in the measurement are positively correlated to one another. The closer the estimated Cronbach's alpha coefficient approaches to the value 1, the higher the internal reliability of the multi-item scales.

According to Salkind (2006), the reliability of data exist if there is repeated testing to measure the same thing which came up with a same result. Reliability is to test the stability of measurement used. The nearer the Cronbach Alpha to the value of 1, the highest the reliability it is. Table 3.1 shows the interpretation of Cronbach Alpha value based on Hair et al (2003).

Table 3.1: Interpretation of Cronbach's Alpha Value

Alpha Value	Interpretation
< 0.6	Weak
0.6 to < 0.7	Moderate
0.7 to < 0.8	Good
0.8 to < 0.9	Very Good
> 0.9	Excellent

3.3.2 Descriptive Analysis

According to Hong (2007) the descriptive analysis which it involving frequencies were carried out to establish the percentage of talent management and competency as perceived by academician. Descriptive statistics are used to describe the basic features of the data in a study. They provide simple summaries about the sample and the measures. Together with simple graphics analysis, form the basis of virtually every quantitative analysis of data. Descriptive statistics such as maximum, minimum, means, standard deviations and variance were obtained for the interval-scaled independent variables and dependent variables.

3.4 CONCLUSION

The conclusion to be drawn is to see what the methodology used in order to get information. Research methodology explains about how the data are used to know the details of rainwater harvesting and potential of this system to overcome water crisis in Klang Valley. This is obtaining through several methods such as observation, interview and case study.

CHAPTER 4

Chapter 4

CASE STUDY

4.1 INTRODUCTION

This chapter will review three (3) case studies to lead this dissertation parallel with objectives and scope that has been set. The case studies involve two (2) government building which are Department of Irrigation and Drainage (JPS) Malaysia headquarters and Ministry of Energy, Green Technology and Water (KeTTHA) and one (1) case study is private building which is National Hydraulic Research Institute of Malaysia (NAHRIM). Selection of case studies based on building that has been used rainwater harvesting system and location of the building. These building are Located Klang Valley, as mentioned in scope of study.

Each of the case studies is using different rainwater harvesting system, different purpose and materials. General information of case studies, system has been used; material used for rainwater harvesting system will be described in this chapter. Each system material selection has different benefits and problems. Thus, conclusion and recommendation can be making for better system of rainwater harvesting in future.

4.2 NATIONAL HYDRAULIC RESEARCH INSTITUTE OF MALAYSIA (NAHRIM)

4.1.1 Background

National Hydraulic Research Institute of Malaysia (NAHRIM) establish in 1990 as a result from Delft Hydraulic & Co findings. The establishment of NAHRIM as a research institute with a capability to conduct experimental simulation and numerical hydrodynamic analysis, ecological and morphological processes and its interaction with human activities. NAHRIM started its operation in September 1995 and move ahead to become an excellent centre in hydraulic engineering research and supporting service to meet the demand from both public and private sector in the water related development and based at Seri Kembangan.

4.1.2 Location

Address: National Hydraulic Research Institute of Malaysia (NAHRIM)
Ministry of Natural Resources & Environment (NRE)
Lot 5377,
Jalan Putra Permai,
43300 Seri Kembangan Selangor Darul Ehsan,
Malaysia.

Map:

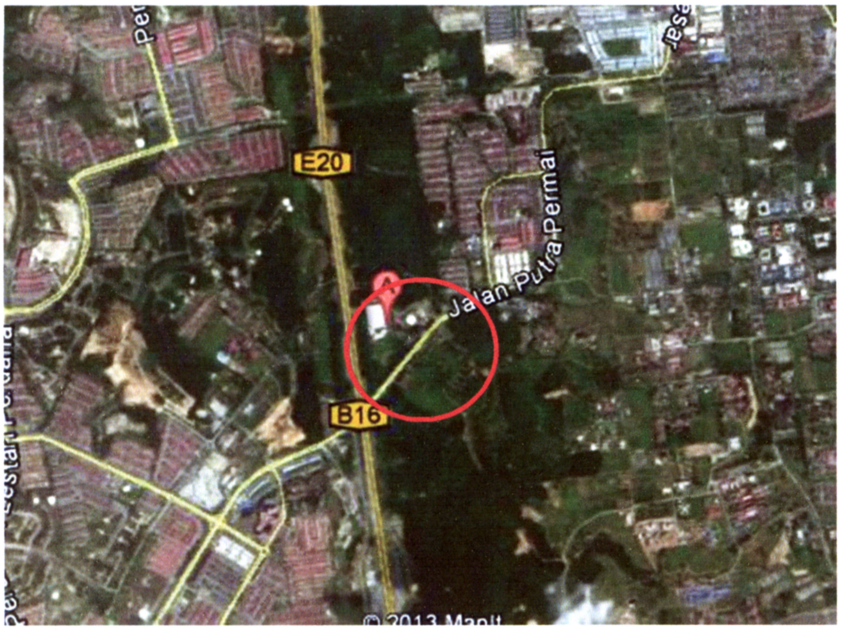


Figure 4.1: NAHRIM is nearing to Kuala Lumpur- Putrajaya Highway.
(Source: Google earth)

Figure 4.2: Aerial photo of NAHRIM
(Source: Google earth)

4.1.3 Rainwater Harvesting System

In NAHRIM, rainwater harvesting is used to flush toilet, irrigation of landscape, rainwater harvesting garden, air conditional system and simulation pond for conducting experiments. Generally, NAHRIM has a large warehouse that used for simulation of hydrodynamic and it was use as catchment approximate 10m × 10m the size. During rainy day, the catchment area will harvest the rainwater before gutter and conveyor pipe transfer the rainwater into the main storage at opposite of the building. Harvested rainwater in the main storage tank will pump to secondary storage that at rooftop and cooling tower for air conditional system using motor pump. Lately, rainwater harvesting is not used for air conditional system due failure water level gauge metre for cooling tower. Harvested rainwater at secondary storage tank will through filtration system before the rainwater distribute to each toilet for flushing system. Figure 4.3 show in generally sequence of rainwater before it used for flushing and landscape irrigation.

In NAHRIM, rainwater and water supply from Syarikat Bekalan Air Selangor (SYABAS) flow in same pipe to toilet. Rainwater is main water supply to flushing and water supply from SYABAS is secondary. There is a device to measure water level in harvested rainwater tank. There are outside building components of rainwater harvesting system. At NAHRIM first-flush system is not be used. The basic components of rainwater harvesting system in NAHRIM are storage tank, conveyor system, catchment area and filtration system and additional system is water pump.

Figure 4.3: sequence of rainwater harvesting flow in NAHRIM

(Source: Stromsaver and Rainwater Harvesting)

4.2.4 Component of Rainwater Harvesting System.

Generally, there are 4 basic component of rainwater harvesting systems which are catchment area, gutter, conveyor system and storage tank. Catchment area used to harvest rainwater during rainfall and size of catchment area will be determining capacity of rainwater. Gutter and conveyor system is use to transfer rainwater form catchment area to storage tank. Storage tank is used to store rainwater and the size of tank will be determined by numbers of user and usage for irrigation or other purpose. In NAHRIM, additional of rainwater harvesting is made to more efficient and effective system. The additional components are a water pump and filtration system. Table below shows basic component of rainwater harvesting and specification.

Components	Size	Material
Catchment area	10m × 10m	Coated metal deck
Gutter	600mm	Polyvinyl Chloride (PVC)
Conveyor system	300mm	Polyvinyl Chloride (PVC)
Storage tank	$10m^3$	Concrete

4.1: Basic components of rainwater harvesting system and specification.

4.2.4.1 Storage Tank

Figure 4.4: underground harvested rainwater tank

Figure 4.5: Image inside underground harvested rainwater tank.

Figure 4.6: Rainwater down pipe as conveyor rainwater from gutter to storage tank.

4.2.4.2 Conveyor System.

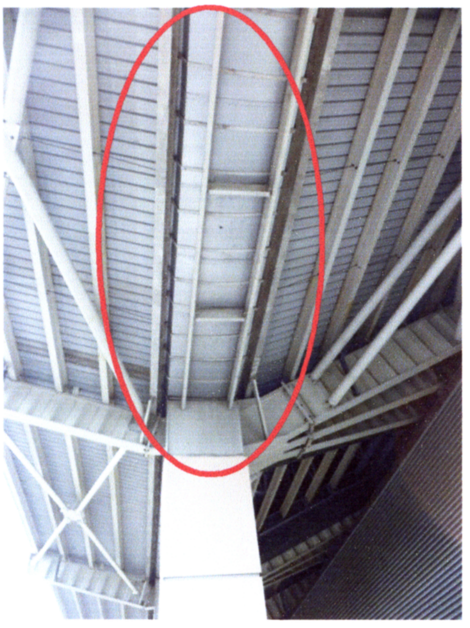


Figure 4.7: gutter that used to collect rainwater.

Figure 4.8: rooftop rainwater harvesting storage tank.

4.2.4.3 Filtration

Figure 4.9: filtration system.

4.2.4.4 Toilet components

Figure 4.10: urinal bowl used harvested rainwater.

Figure 4.11: urinal flush used harvested rainwater.

Figure 4.12: water closet (WC) used rainwater harvesting.

Figure 4.13: water closet (WC) used rainwater harvesting to flushing.

4.3 DEPARTMENT OF IRRIGATION AND DRAINAGE (DID).

4.3.1 Background

Department of Irrigation and Drainage (DID) is a government bodies that provide service in flood management, river management, coastal management, water sources management and hydrology, storm water management and dams. DID was establish in 1932 and known as Public Works Department, Federated Malay Stated to provide irrigation and drainage. In 1963, DID was establish in Sabah and Sarawak due to formation of Malaysia. Nowadays, service provided DID more wide and efficient. In this study, headquarter DID is one of building that use rainwater harvesting system.

4.2.2 Location

Address: Department of Irrigation & Drainage Malaysia,

Jalan Sultan Salahuddin,

50626 Kuala Lumpur,Malaysia.

Map:

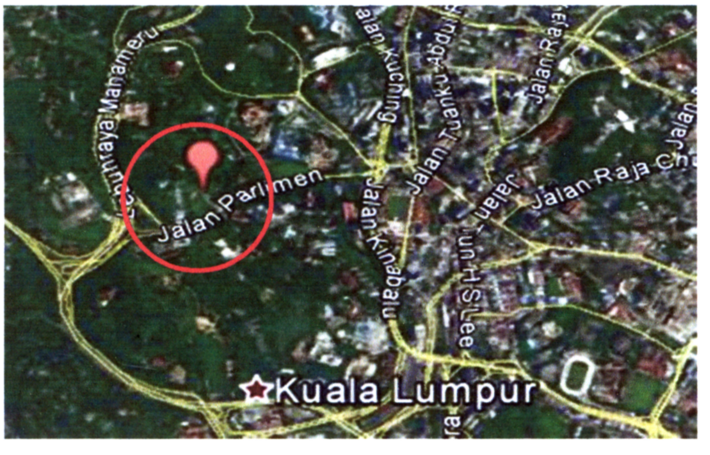


Figure 4.14: Key plan of DID and it is nearing to Mahameru Highway and Parlimen Road.

(Source: Google earth)

4.3.3 Rainwater Harvesting System

At headquarter Department of Irrigation and Drainage has two system rainwater harvesting installed which at block A and block B. in this study, block B is selected because system of rainwater harvesting use gravity to distribute water to toilet. Block B used rainwater harvesting for non-portal water and more specific is to flushing toilet. This building used 8 numbers of tanks and the tanks placed at hang-over. The building has 4 stores and each store has two tank and the tanks is connected by balancing pipe to ensure water level for both at same level. The installation of rainwater harvesting system made in 2012. This system consist filtration and first-flush to increase rainwater quality.

To distribute rainwater from tank to toilet, 1 inch PVC pipe is use. Rainwater harvesting system is main water supply for flushing and water supply from SYABAS is secondary and same with NAHRIM. During installation this system, existing pipe system has be cut-off and new piping system provided using PVC pipe. Below are figure of rainwater harvesting system.

In DID, usage of harvested rainwater is record to identify effectiveness of the system and measure usage of rainwater to flushing. Data usage will be analysis monthly and data will collect from data logger and metre at each floor.

4.3.4 Components of rainwater harvesting system

In Block B DID building using gravity energy to deliver harvested rainwater to each toilet, thus, the components in DID building is simple and basic components. The components of rainwater harvesting in DID building are catchment area, gutter, conveyor system, storage tank and additional filtration and first-flush. Table below shown specification of rainwater harvesting in DID.

Components	Size	Materials
Catchment area	$100m^2$	concrete
Gutter	150mm	Polyvinyl Chloride (PVC)
Conveyor system	120mm	Polyvinyl Chloride (PVC)
Storage tank	1000 litre	high density polyethylene (HDPE)

4.2: Basic components of rainwater harvesting system and specification.

4.3.4.1 Storage Tank

Figure 4.15 storage tanks with buoys for rainwater.

Figure 4.16 storage tank buoys to measure water level.

Figure 4.18: overflow pipe of rainwater harvesting tank.

Figure 4.19: balancing pipe for storage tank.

4.3.4.2 Filtration

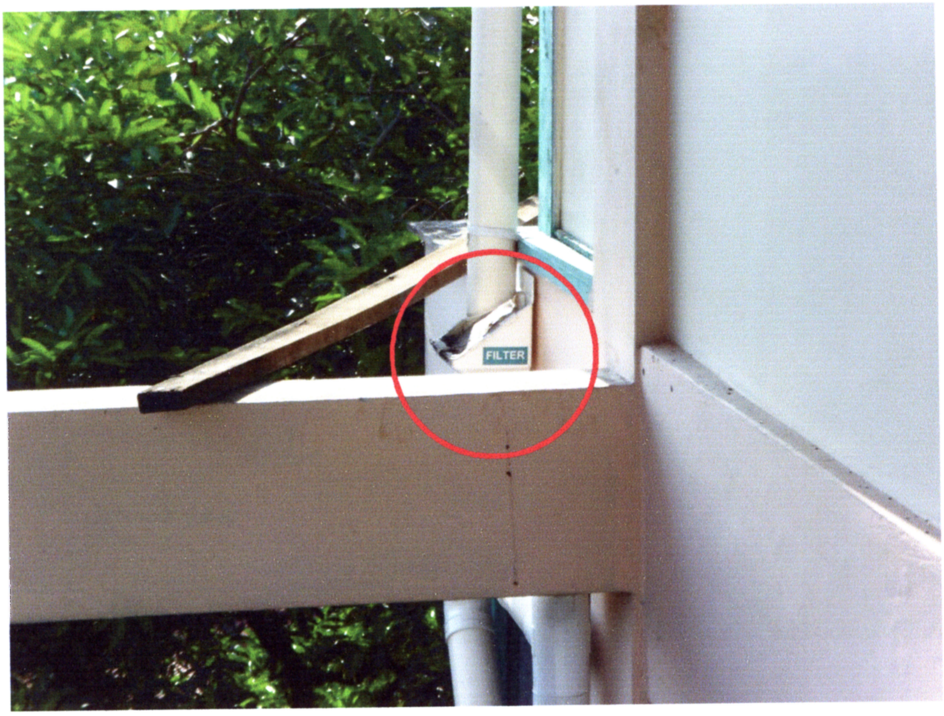


Figure 4.15: rainwater filter and first-flush.

4.3.4.3 Catchment Area

Figure 4.19: catchment area at block B DID headquarters.

Figure 4.20: gutter of rainwater harvesting system.

4.3.4.4 Data Logger

Figure 4.21: data logger of rainwater harvesting usage.

4.3 MINISTRY OF ENERGY, GREEN TECHNOLOGY AND WATER (KeTTHA).

4.3.1 Background

Ministry of Energy, Green Technology and Water building a project by the Government with technical input on Energy Efficiency from DANIDA (Danish International Development Assistance). KeTTHA building has 2 blocks which are E4 and E5 of 6-storey high buildings excluding 2 levels of basement parking and approximately 19,732 m^2 of air-conditioned area. The estimate cost for building construction is RM 50 Million and construction stated in March 2002. The completion of building is on September 2004 with 2 year construction period. KeTTHA building was certified Silver medal in December 2001 from Green Building Index (GBI). The building becomes benchmark for green building and reference to other building.

4.3.2 Location

Address: Ministry of Energy,Green Technology and Water Block E4/5 Parcel E,

Federal Government Administrative Centre, 62668,

Putrajaya.

Map:

Figure 4.23: location of KeTTHA building.

Figure 4.24: Aerial photo of KeTTHA building.

4.3.3 Rainwater Harvesting System

In general, KeTTHA building is use harvested rainwater for landscaping irrigation. This building use simple rainwater harvesting system without any filtration of rainwater. Rainwater harvested from canopy roof at top of building and convey to storage tank on rooftop. Irrigation of landscape conduct 2 time daily which at 9.00 am and 5.00 pm. The area of irrigation landscape at ground floor level, level 3 and level 7 (rooftop).

Canopy roof also known as butterfly roof design to maximizing quantity of rainwater collection. On the building, catchment area only used half of canopy roof that located at roof top and other function of canopy roof is minimize solar radiation from sun. Approximate size of catchment is 250m^3 and the rainwater will deliver to storage tank using PVC pipe with size 150mm. There has 2 unit of storage tank with balancing pipe to ensure level water is equal for both tank before it used for irrigation. Level of rainwater determine by buoy, if the water reach at minimum level, water supply from SYABAS take responsible to supply water into the storage tank.

This building used the harvested rainwater to irrigate landscaping at level 7th, 3rd, and ground level. To ensure water flow and water pressure for irrigation, 2 unit of motor are used to maintain water flow and pressure. Motor was set in mode automatic for irrigation purpose. Below show an image merely with system that has been used in KeTTHA building.

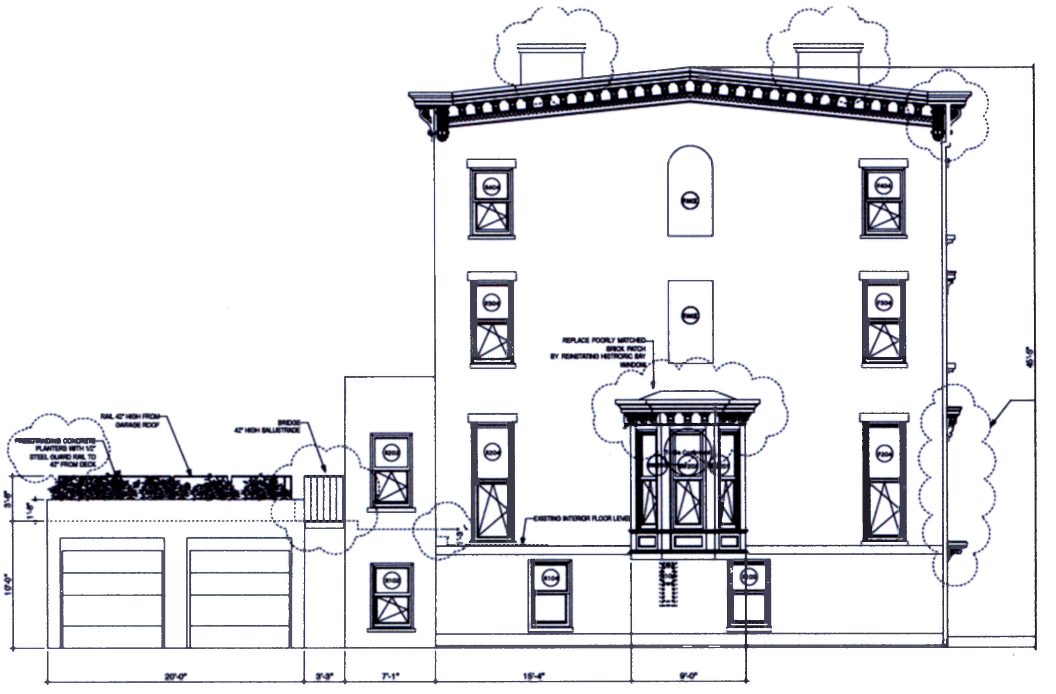


Figure 4.25: diagram rainwater harvesting system that merely with KeTTHA building.

(Source: 228washington.com)

4.3.4 Components of Rainwater Harvesting.

The component of rainwater harvesting system was design for irrigation purpose but it has same basic components with two case studies above. The basic components in KeTTHA building are catchment area, gutter, conveyor system and storage tank. An additional component is motor pump to deliver rainwater to landscape. Table below show the components specification of rainwater harvesting system in KeTTHA building.

Components	Size	Materials
Catchment area	25m×10m	Coated metal deck
Gutter	200mm	concrete
Conveyor system	150mm	Polyvinyl Chloride (PVC)
Storage tank	6 m^3	Galvanise Iron (GI)

Table 4.3: Basic components of rainwater harvesting system and specification.

4.3.4.1 Catchment Area

Figure 4.26 Catchment areas for KeTTHA building.

Figure 4.27: Gutter to convey rainwater.

4.3.4.2 Storage Tank

Figure 4.27: Harvested rainwater storage tank.

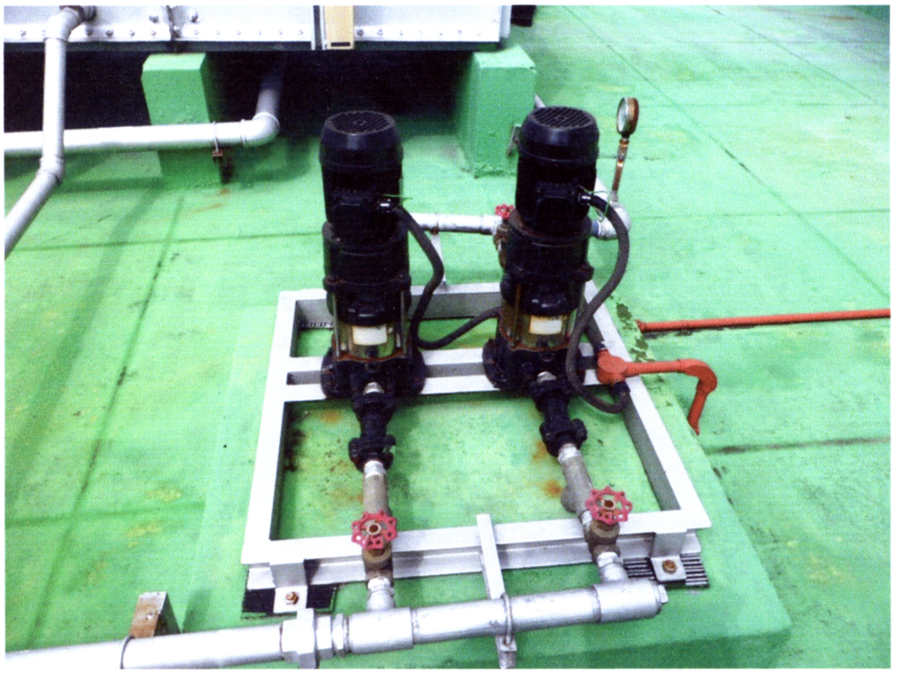


Figure 4.28: Water pump for landscape irrigation.

4.3.4.3 Landscaping Area

Figure 4.29: Landscape at ground level.

CHAPTER 5

Chapter 5

Introduction

The goal of this study was to measure knowledge, benefits, problems and barrier implementing rainwater harvesting system to overcome water crisis in Klang Valley. This chapter provide a detailed analysis of the statistical methods and procedure that were used to translate the collected survey data into valid conclusion in response to the literature review. This chapter contains the data collection process and validation methods used in the study. Besides, it also gives a specific view regarding descriptive statistic of the respondent's details, the reliability for variable and opinion from respondents about rainwater harvesting system.

5.1 RELIABILITY ANALYSIS

5.1.1 Reliability Analysis Knowledge

The Table 5.1 below present the Cronbach's alpha coefficient depicts the reliability levels of knowledge rainwater harvesting system. The reliability of knowledge rainwater harvesting system is 0.917. The value present the consistency of respondent answering questionnaire and most of respondents is user rainwater harvesting system as a factor consistency of answer. Thus, the Cronbach's Alpha reliability values of knowledge of rainwater harvesting system were acceptable and most of respondent has general knowledge about this system.

Cronbach's Alpha	N of Items
.917	5

Table 5.1: Knowledge of Rainwater Harvesting Reliability Statistic.

Item Statistics

	Mean	Std. Deviation	N
You know it work?	3.89	1.061	44
Suitable for office and home	3.84	1.098	44
Did you know where to install it?	3.57	1.421	44
It has been used before in Malaysia	3.86	1.091	44
It is safely to used	3.91	1.053	44

Table 5.2: Reliability Statistic each item for knowledge rainwater harvesting system

The Table 5.1 below present the reliability statistic each item of knowledge rainwater harvesting system. The highest reliability of knowledge rainwater harvesting system is 3.91 which is rainwater harvesting is safely to used and the lowest mean value is 3.57 which is knowledge installation of rainwater harvesting system. In urban area, rainwater possibly contaminated by particles, heavy metals and organic air pollutants (Helmreich & Horn, 2008). From analysis respondent agree rainwater harvesting is safely to use after filtration and first flush method. To prevent these pollutants from entering the storage tank, the first rainwater containing the debris should be diverted or flushed. Automatic devices that prevent the first 20-25 litres of runoff from being collected in the storage tank are recommended (Khoury-Nolde, nd). . Harvested rainwater secured from contamination after passing treatment and filtration (Mosley, 2005). Thus, rainwater harvesting system has safely to use after filtration of harvested rainwater.

The lowest mean is about installation of rainwater harvesting components. Most of the respondents are user of rainwater harvesting system and their not involving design, construction or maintenance of this system. Their only has general knowledge about rainwater harvesting system. Second lowest mean value is suitable for office and home which is 3.84. All of respondents used rainwater harvesting system in their office and their agree rainwater harvesting system also can be used in their home. Lastly, mean value for rainwater harvesting system has been used in Malaysia which is 3.86. Rainwater harvesting has a long tradition for a long of years. It is a technology used for collecting and storing rainwater from roof surface, land surfaces or rock catchments with a simple technique such as natural and artificial ponds and tank (Helmreich & Horn, 2008). The statement shown rainwater harvesting is traditional method for clean water sources before piping water supply created.

5.1.2 Reliability Analysis Benefits of Rainwater Harvesting

Table 5.3 and table 5.4 below show the Cronbach's alpha coefficient depicts the reliability levels and statistic each item of benefits rainwater harvesting system. The reliability value for benefits of rainwater harvesting system is 0.926. Thus, the Cronbach's Alpha reliability values of benefits of rainwater harvesting system were acceptable and most of respondents understand and know about benefits of this system.

Reliability Statistics

Cronbach's Alpha	N of Items
.926	9

Table 5.3: Reliability Statistics for Benefits of rainwater harvesting system

Item Statistics

	Mean	Std. Deviation	N
Clean source of water	3.77	.743	44
Easy to operate and manage	3.55	.761	44
Reduce storm water runoff	3.80	.878	44
Cost saving for water bill	4.16	1.010	44
Simple and flexible technology	3.93	.695	44
Friendly to landscaping and gardening	3.93	.873	44
Low operation cost	3.34	1.010	44
Can overcome water crisis	4.07	.974	44
Minimize soil erosion	3.55	.791	44

Table 5.4: Reliability Statistic each item for benefits rainwater harvesting system.

Form analysis above, respondents agree rainwater harvesting has lot benefits such as clean water sources, easy to manage and operate, reduce storm water run-off, reduce water bill and etc. According to Khoury-Nolde, (nd), rainwater is free and clean water sources is proven from analysis above because most of respondent agree with Khoury-Nolde rainwater is clean water sources and minimize soil erosion. Khoury-Nolde also stated rainwater harvesting system is easy to operate and manage by the owner itself. Mean value for easy to operate and manage and minimize soil erosion is 3.55, it represent respondents moderately understand with both of benefits rainwater harvesting system. According from NAHRIM, September 2010, a desktop study on impact of rainwater harvesting utilization system on flood reduction found, rainwater harvesting has big potentials for utilized flash flood. Thus, analysis above shown majority of respondents agrees with rainwater harvesting can reduce storm water and it is proven by NAHRIM from his desktop study in Sunagi Damansara.

Based on Helmreich & Horn, (2008), rainwater harvesting system is a technology used for collecting and storing rainwater from roof surface, land surfaces or rock catchments with a simple technique such as natural and artificial ponds and tanks, this evidence supported from majority of respondent during survey is carry out. Analysis has made and the result 3.93 mean value for rainwater harvesting is a simple and flexible technology. The value show most respondents agree with statement from Helmreich & Horn. NAHRIM stated, rainwater harvesting system at RM 1.63/m3 is cheaper compared with the piped water cost of RM 1.70/m3. Rate of rainwater harvesting system consider installation and supply costs according to materials usage. Analysis above shown mean value for costs saving for water bill is 4.16. Thus, respondent agree rainwater harvesting is costs saving for water bill. Harvested rainwater can be source in households for drinking, cooking, sanitation, as well as for productive use in agriculture and landscape watering (Helmreich & Horn, 2008).

From analysis indicated mean value for rainwater harvesting system is friendly to landscaping and gardening is 3.93 it present rain water harvesting system is Friendly to landscaping and gardening and one of case studies used rainwater harvesting system for landscaping irrigation. Low running costs for rainwater harvesting system (Khoury-Nolde, nd). Mean value for low running costs is 3.34 presenting rainwater harvesting system has high running costs. From observation, rainwater harvesting has low running costs because it is used simple technology. Rainwater harvesting components are gutter, pipes, storage tank, water pump, catchment, and buoy for water level. Thus, the components not required electrical supply except water pump to operate and electrical consumption for water pump is minimum consumption.

The abundant annual rainfall, scarcity of potable surface and ground water suggests that rainwater harvesting has a huge potential to solve fresh water scarcity (Chistina, 2009). Analysis shown mean value for rainwater harvesting can overcome water crisis in highest value which is 4.07 and respondents strongly agree rainwater harvesting system can overcome water crisis.

5.1.3 Reliability Analysis for Problems and Barrier of Rainwater Harvesting

Reliability Statistics

Cronbach's Alpha	N of Items
.816	6

Table 5.5: Reliability Statistics for problems and barrier of rainwater harvesting system

Item Statistics

	Mean	Std. Deviation	N
Mosquito breeding	3.84	.834	44
Unfriendly design and take much space	3.02	.731	44
High initial cost for installation	3.61	.970	44
Low storage capacity	3.14	.905	44
Rainwater possible contaminated/ polluted	3.30	.878	44
Storage tanks can be unsafe for children	3.07	1.043	44

Table 5.6: Reliability Statistic each item for problems and barrier rainwater harvesting system.

Table 5.5 and table 5.6 above show the Cronbach's alpha coefficient depicts the reliability levels and statistic each item of benefits rainwater harvesting system. The reliability value for benefits of rainwater harvesting system is 0.816. Thus, the Cronbach's Alpha reliability values of problems and barrier of rainwater harvesting system were acceptable and most of respondents understand and know about problems and barrier of this system.

From analysis above, mosquito breeding is the main problem of rain water harvesting system in Malaysia. According to Mohd. Shahwahid et al., (2007), mosquito breeding is a factor to implementing rainwater harvesting system. Mean value of mosquito breeding is 3.84 and it is the high mean from above problems and barrier has stated in questionnaire. From observation at three case studies found, mosquito breeding on storage tank is logical theory problem and it is no evidence to proven. Storage tank at three of case studies, mosquito breeding is not an issue to implementing rainwater harvesting system. Proper manage of storage tank can prevent mosquito breeding. According to Shaaban et al., (2008), rainwater utilization campaign should lead and provide a solution for prevention of mosquito breeding for rainwater harvesting system.

Other problems and barrier are unfriendly design and take much space, according to Mohd. Shahwahid et al., (2007) rainwater harvesting system is difficult to implement due to the unfriendly design which had taken too much space in the backyard. From analysis above shown unfriendly design and take much space is a not problems and barrier to implementing rainwater harvesting and the mean value is 3.02. The storage tank can be place underground and above ground (Building codes division, nd). From observation on case studies, storage tank place on underground, rooftop and hang over of the building, thus storage tank does not interrupt walk way area or backyard space.

High initial costs for installation of rainwater harvesting system are other factor barrier to enhance this system in Malaysia. Analyses above shown 3.61 mean value for high initial costs for installation. Installation of rainwater harvesting costs depending material selection and type of rainwater harvesting system. The hypothesis can make is more complex of rainwater harvesting system, higher the costs of installation. Khoury-Nolde, initial costs installation of rainwater harvesting depends on materials selection during designing the system. According to NAHRIM, approximate cost for installation rainwater harvesting system on two storey terrace house around RM2700.00 and the return in 15 years to 16 years, cost estimate in year 2001.

Other problems and barrier of rainwater harvesting are low capacity storage, Khoury-Nolde stated low capacity storage will limit rainwater to harvested, therefore large storage is needed and costs of construction increase. According table above, low capacity storage is not main issue to implementing rainwater harvesting system because size of storage depends on numbers of user, water consumption, size of catchment area and few factor that related with size of storage tank. According to Helmreich & Horn, 2008, in urban area, rainwater possibly contaminated by particles, heavy metals and organic air pollutants. From the table 5.6 contaminants and polluted mean value is 3.30 and it represent rainwater is contaminated but rainwater quality can be improve by filtration and first flush. The quality of stored water can be much improved if leaves and other debris are kept out of the system by the use of a coarse filter or screen. Without screens present, leaves and other material may enter tanks and provide food and nutrients for micro-organisms to survive. In the absence of such nutrients, bacteria eventually (2-20 days) die off from starvation (Mosley, 2005).

Last point in problems and barrier of rainwater harvesting system are storage tanks can be unsafe for small children if proper access protection is not provided (Khoury-Nolde, nd). From analysis, mean value for storage tank can be unsafe to children is 3.07 which mean the statement has no strong evidence or any cases to refer storage tank is unsafe. Thus, the respondent moderately agree if improper access protection maybe unsafe to children.

5.2 DESCRIPTIVE ANALYSIS

Descriptive statistic is use to describe as the process of collecting, organizing, summarizing and presenting the data for effective decision making. This type of analysis is used to describe the central tendency and measures the dispersion of the answered questionnaire.

5.2.1 Descriptive Analysis of General Information Respondents.

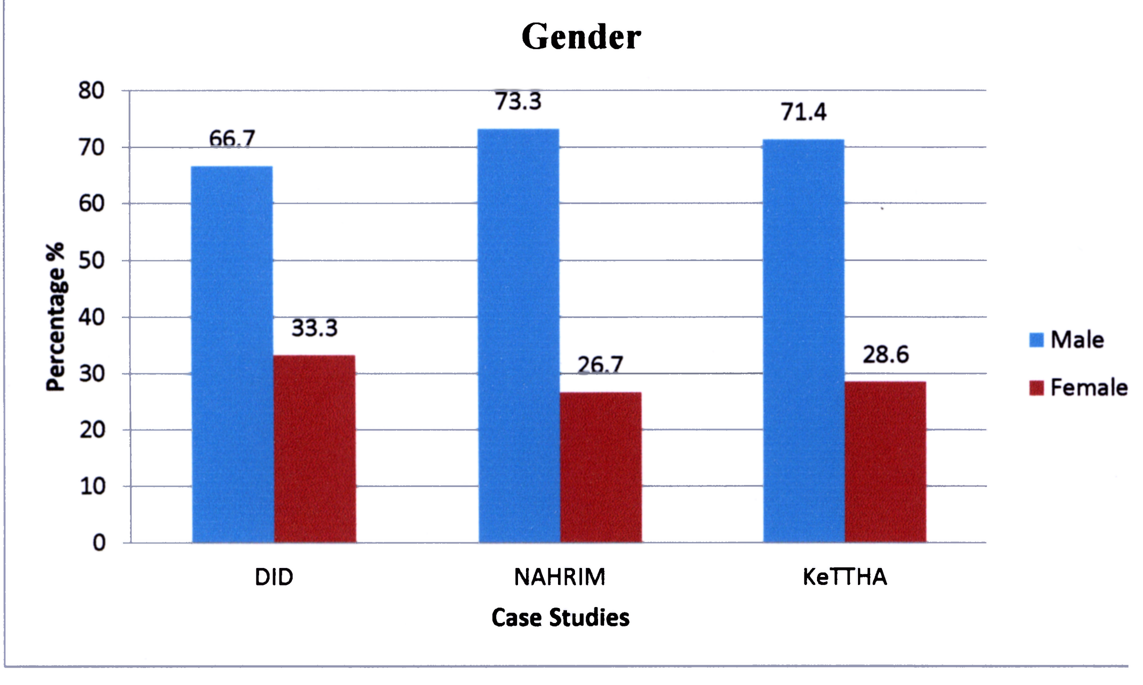


Chart 5.1: Descriptive Analysis of Gender Respondents.

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	31	70.5	70.5	70.5
	Female	13	29.5	29.5	100.0
	Total	44	100.0	100.0	

Table5. 7: Descriptive Analysis of Gender Respondents for Overall.

Table 5.7 and Chart 5.1 above show that there are 13 female respondents and 31 male respondents over 44 respondents. The percentages of female respondent's involvement are 33.3% at DID, 26.7% at NAHRIM, and 28.6% at KeTTHA. The percentages of male respondent's involvement are 66.7% at DID, 73.3% at NAHRIM and 71.4% at KeTTHA. From analysis; shows that female are smaller numbers than male respondents participate in this research

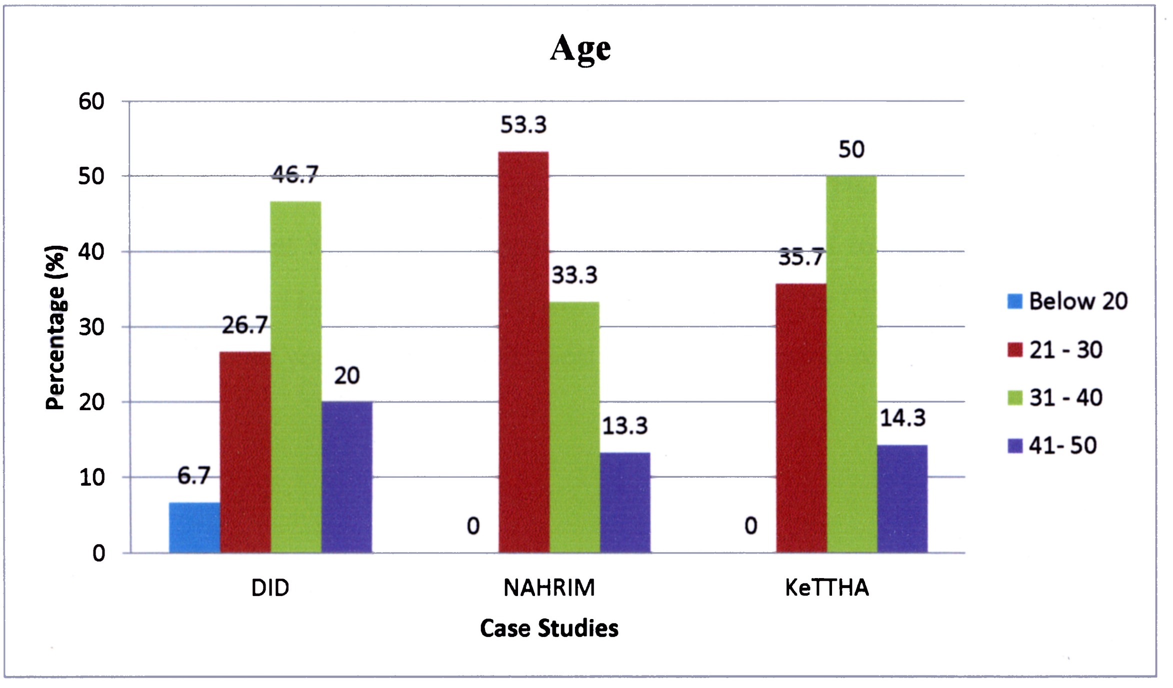


Chart 5.2: Descriptive Analysis of Age Respondents.

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below 20	1	2.3	2.3	2.3
	21-30	17	38.6	38.6	40.9
	31-40	19	43.2	43.2	84.1
	41-50	7	15.9	15.9	100.0
	Total	44	100.0	100.0	

Table5.8: Descriptive Analysis of Age Respondents for Overall.

Based on Chart 5.2 and Table 5.8 above, for respondent's age, there are 1 respondent age below 20 years old in NAHRIM (6.7%), 17 respondents age between 21 to 30 years old which 26.7% at DID, 53.3% at NAHRIM and 35.7% at KeTTHA. 19 respondents age between 31 to 40 years old with which 46.7% at DID, 33.3% at NAHRIM and 50% at KeTTHA. 7 respondents age between 41 to 50 years old and above which 20% at DID, 13.3% at NAHRIM and 14.3% at KeTTHA. Respondents with the age 31 to 40 years old are the highest contributors to this research.

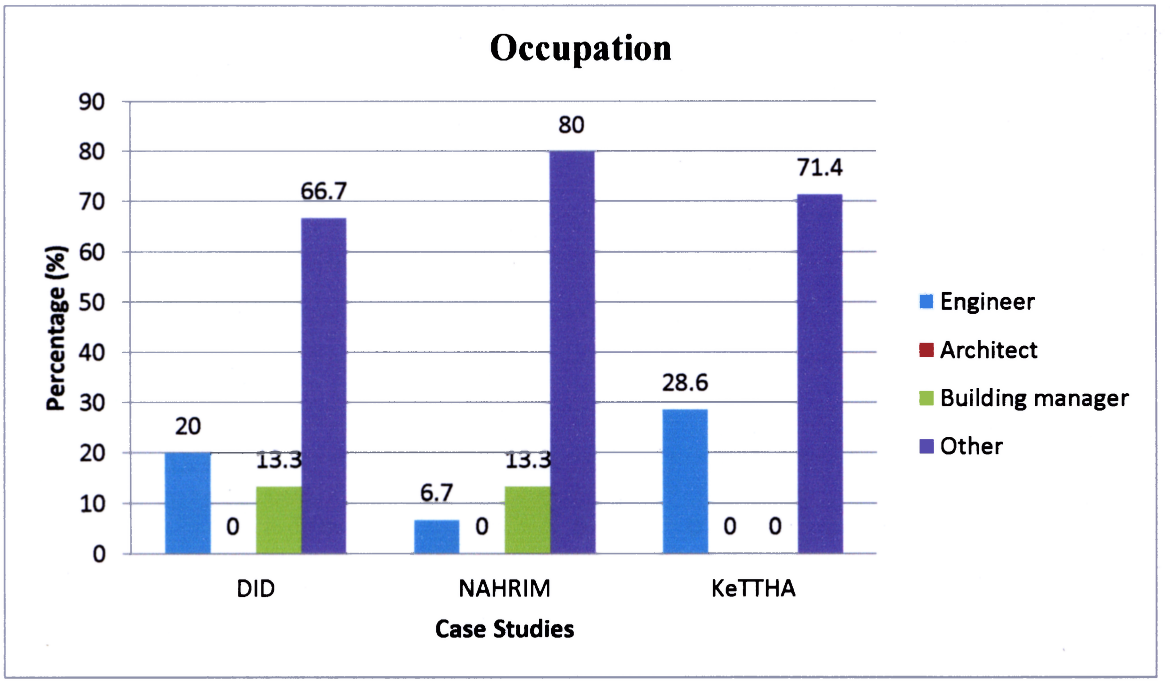


Chart 5.3: Descriptive Analysis of Occupation Respondents.

Occupation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Engineer	8	18.2	18.2	18.2
	Building manager	4	9.1	9.1	27.3
	Other	32	72.7	72.7	100.0
	Total	44	100.0	100.0	

Table5.9: Descriptive Analysis of Occupation Respondents Overall.

According to Chart 5.3 above Table 5.9, 8 respondents or 20% at DID, 6.7% at NAHRIM and 28.6% working as an engineer. 4 respondents were working as a building manager or 13.3% at DID and 13.3% at NAHRIM and 32 respondents working other from an engineer, building manager and architect or 66.7% at DID, 80% at NAHRIM and 71.4%. The majority of the respondents work other from an engineer, building manager and architect.

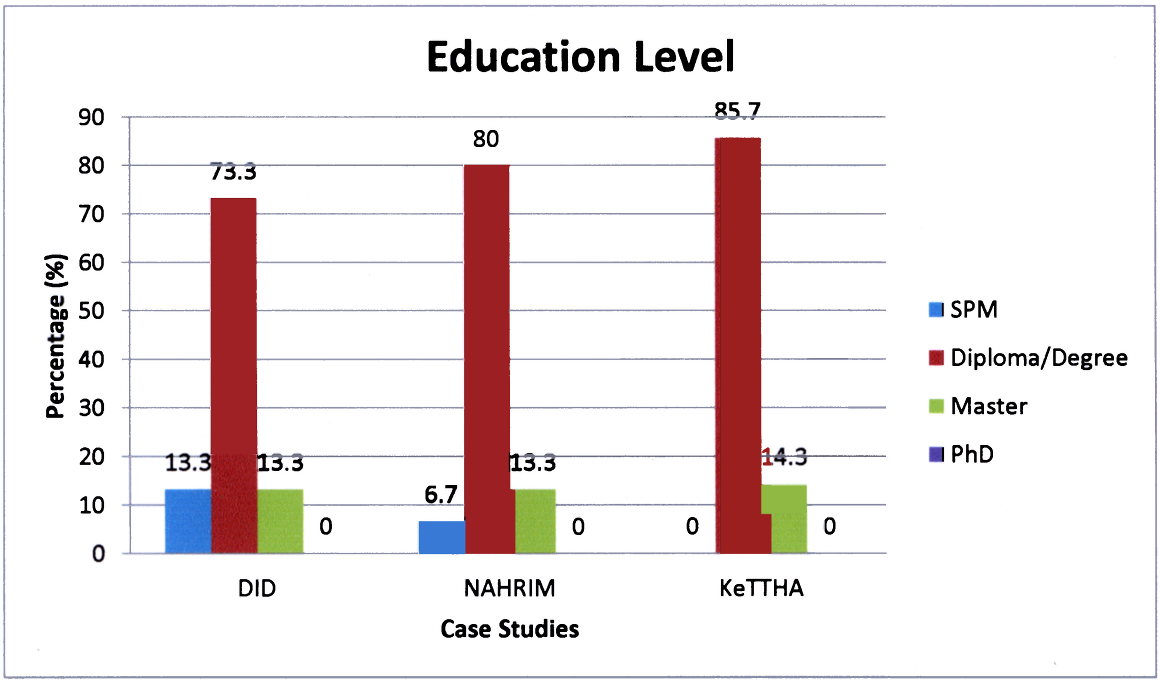


Chart 5.4: Descriptive Analysis of Education Level Respondents.

education Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SPM	3	6.8	6.8	6.8
	Diploma/Degree	35	79.5	79.5	86.4
	Master	6	13.6	13.6	100.0
	Total	44	100.0	100.0	

Table 5.10: Descriptive Analysis of Education Level Respondents Overall.

From the Chart 5.4 and Table 5.10 above, the summarized that 3 respondents or 13.3% at DID and 6.7% had a Sijil Pelajaran Malaysia (SPM) certificate, 35 people or 73.3% at DID, 80% at NAHRIM and 85.7% at KeTTHA respondent had diploma/degree of education level and 6 people or 13.3% at DID, 13.3% at NAHRIM and 14.3% at KeTTHA respondent has master degree of education level. The majority of the respondents had a diploma/degree for their education level.

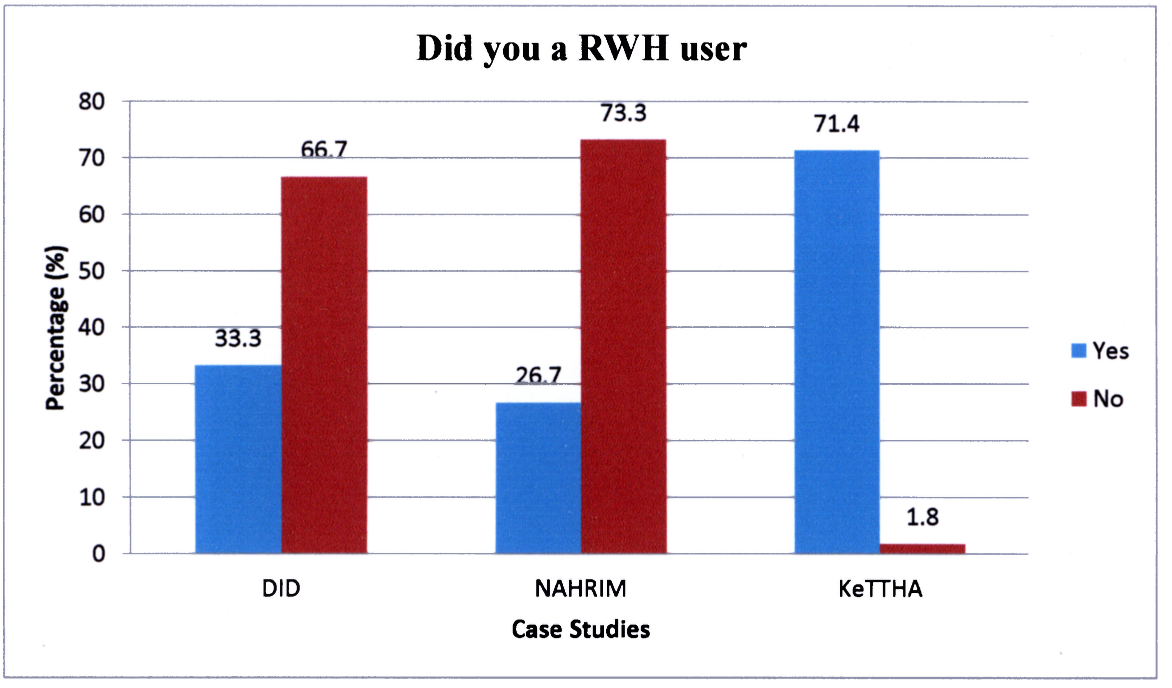


Chart 5.5: Descriptive Analysis of Respondents.

Did you a rainwater harvesting user?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	19	43.2	43.2	43.2
	No	25	56.8	56.8	100.0
	Total	44	100.0	100.0	

Table 5.11: Descriptive Analysis of Respondents Overall.

The above Table 5.11 and Chart 5.5 showed respondents is a user of rainwater harvesting system. There are 19 respondents or 33.3% at DID, 26.7% at NAHRIM and 71.4% at KeTTHA as a user of rainwater harvesting system and 25 respondents or 66.7% at DID, 73.3% at NAHRIM and 1.8% at KeTTHA as a user of rainwater harvesting system. The majority of respondents are not a user of rainwater harvesting system

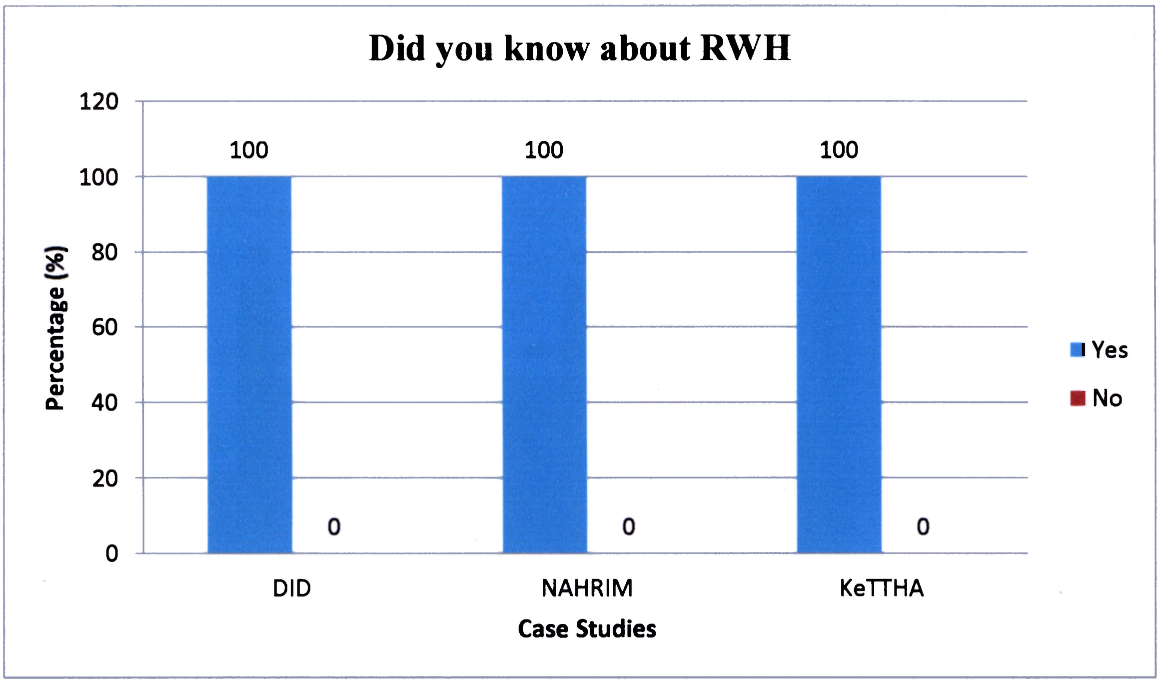


Chart 5.6: Descriptive Analysis of Respondents.

Did you know about rainwater harvesting?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	44	100.0	100.0	100.0

Chart 5.12: Descriptive Analysis of Respondents Overall.

Table 5.30 and figure 5.26 above show that there are 44 respondents know about rainwater harvesting. The percentage of respondent's involvement is 100% at each case studies and participates in this research

5.2.2 Knowledge of Rainwater Harvesting System

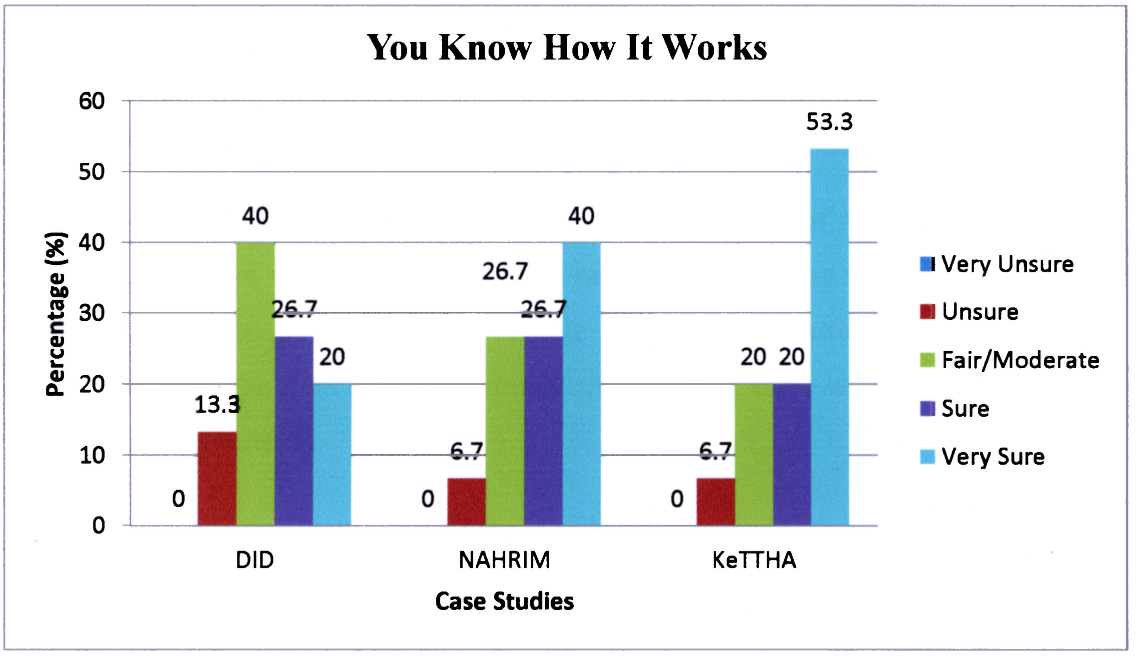


Chart 5.1: Descriptive analysis for operation of rainwater harvesting system.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Unsure	5	11.4	11.4	11.4
	Fair / Moderate	12	27.3	27.3	38.6
	Sure	10	22.7	22.7	61.4
	Very Sure	17	38.6	38.6	100.0
	Total	44	100.0	100.0	

Table 5.12: Descriptive analysis of operation of rainwater harvesting system for overall.

Chart 5.7 and Table 5.12 above show that there are 5 respondents unsure operation system of rainwater harvesting and it is represent 13.3% at DID, 6.7% at NAHRIM and KeTTHA. The percentage for fair/ moderate know about operation system of rainwater harvesting is 40% at DID, 26.7% at NAHRIM, 20% at KeTTHA and numbers of respondents is 12 people. 10 respondents sure about operation system of rainwater harvesting system and among or percentage are 27.6% at DID and NAHRIM and 20% at KeTTHA. For very sure know operation of rainwater harvesting are 20% at DID, 40% at NAHRIM and 53.3% which mean 17 numbers of respondents. Therefore, total numbers of respondents are 44 people.

Over than half of respondents know about operation system of rainwater harvesting because majority of respondents are user of rainwater harvesting system and working in department which manage and operate rainwater harvesting system. Unsure respondent might be from other department and there are know well about the system that used in the building.

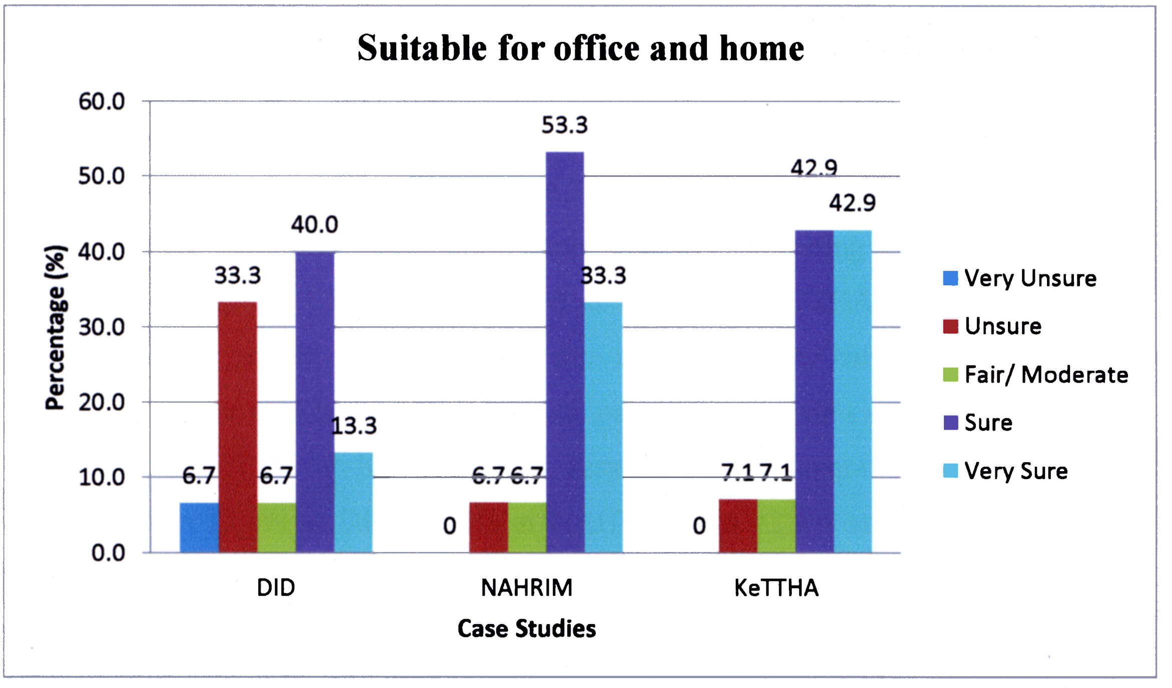


Chart 5.8: Descriptive analysis of rainwater harvesting is suitable for office and home.

Suitable for office and home

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Unsure	1	2.3	2.3	2.3
	Unsure	7	15.9	15.9	18.2
	Fair / Moderate	3	6.8	6.8	25.0
	Sure	20	45.5	45.5	70.5
	Very Sure	13	29.5	29.5	100.0
	Total	44	100.0	100.0	

Table 5.13: Descriptive analysis of rainwater harvesting is suitable for office and home for overall.

Chart 5.7 and Table 5.13 above show that there is 1 of respondent very unsure rainwater harvesting suitable for office and home and it is represent 6.7% at DID. 7 of respondent state that their unsure rainwater harvesting suitable for office and home and it is represent 33.3% at DID, 6.7% at NAHRIM and 7.1% at KeTTHA. The percentage for fair/ moderate know about rainwater harvesting suitable for office and home is 6.7% at DID and NAHRIM and 7.1T at KeTTHA and numbers of respondents is 3 people. 20 respondents sure about rainwater harvesting system is suitable for office and home and among or percentage are 40% at DID, 53.3% at NAHRIM and 42.9% at KeTTHA. For very sure know operation of rainwater harvesting are 13.3% at DID, 33.3% at NAHRIM and 42.9% at KeTTHA which mean 13 numbers of respondents. Therefore, total numbers of respondents are 44 people and there is no missing or deleted respondent.

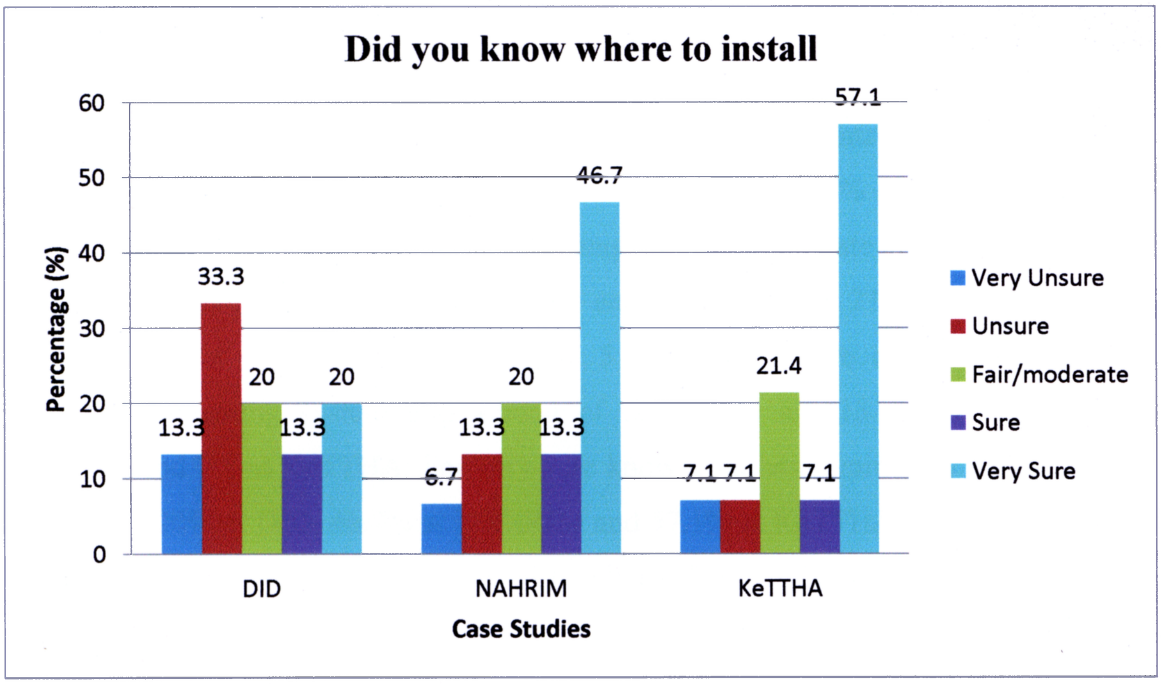


Chart 5.9: Descriptive analysis of Installation Rainwater Harvesting System.

Did you know where to install it?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Unsure	4	9.1	9.1	9.1
	Unsure	8	18.2	18.2	27.3
	Fair / Moderate	9	20.5	20.5	47.7
	Sure	5	11.4	11.4	59.1
	Very Sure	18	40.9	40.9	100.0
	Total	44	100.0	100.0	

Table 5.14: Descriptive analysis for installation rainwater harvesting system for overall.

Based on Chart 5.9 and Table 5.14 above show that there are 4 of respondent's very unsure installation rainwater harvesting system and it is represent 13.3% at DID, 6.7% at NAHRIM and 7.1%. 8 of respondent state that their unsure installation rainwater harvesting system and it is represent 33.3% at DID, 13.3% at NAHRIM and 7.1% at KeTTHA. The percentage for fair/ moderate know installation rainwater harvesting system is 20% at DID and NAHRIM and 21.4% at KeTTHA and numbers of respondents is 9 people. 5 respondents sure about installation rainwater harvesting system and among of percentage are 13.3% at DID and KeTTHA and 7.1 at KeTTHA. For very sure know installation rainwater harvesting system are 20% at DID, 46.7% at NAHRIM and 57.1% at KeTTHA which mean 18 numbers of respondents. Therefore, total numbers of respondents are 44 people and there is no missing or deleted respondent.

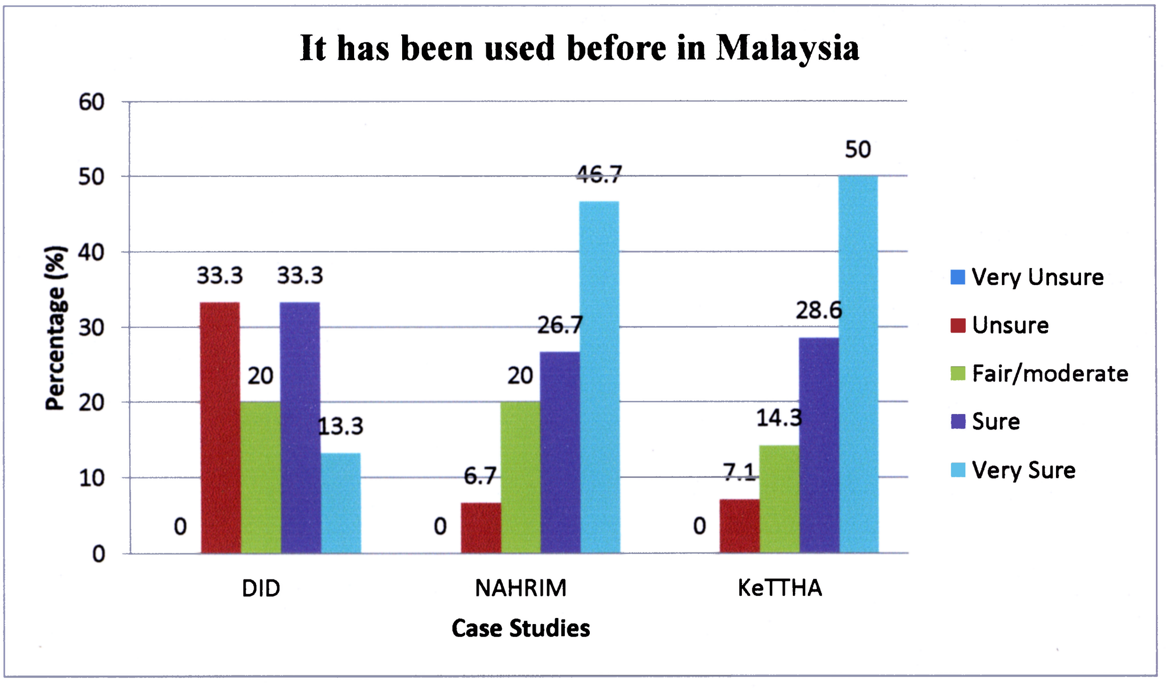


Chart 5.10: Descriptive analysis rainwater harvesting has been used in Malaysia

It has been used before in Malaysia

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Unsure	7	15.9	15.9	15.9
	Fair / Moderate	8	18.2	18.2	34.1
	Sure	13	29.5	29.5	63.6
	Very Sure	16	36.4	36.4	100.0
	Total	44	100.0	100.0	

Table 5.15: Descriptive analysis rainwater harvesting has been used in Malaysia

According to Chart 5.10 and Table 5.15 above show that there are 7 of respondents unsure about rainwater harvesting has been used in Malaysia and it is representing 33.3% at DID, 6.7% at NAHRIM and KeTTHA is 7.1%. 8 of respondent state that their fair/ moderate rainwater harvesting has been used in Malaysia and it is represent 20% at DID and NAHRIM and at KeTTHA is 14.3%. 13 respondents sure about installation rainwater harvesting system and among of percentage are 33.3% at DID, 26.7% at NAHRIM and 28.6%. For very sure know installation rainwater harvesting system are 13.3% at DID, 46.7% at NAHRIM and 50% which mean 16 numbers of respondents. Therefore, total numbers of respondents are 44 people and total cumulative percentage is 100%.

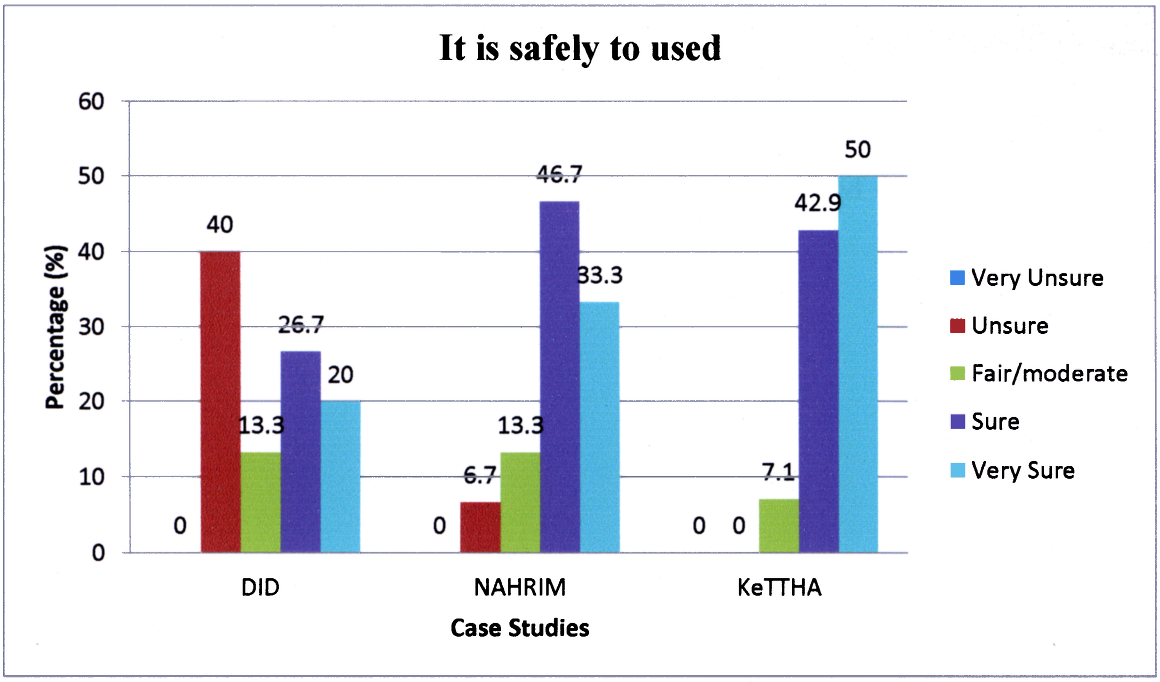


Chart 5.11: Descriptive analysis rainwater harvesting is safely to used.

It is safely to used

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Unsure	7	15.9	15.9	15.9
	Fair / Moderate	5	11.4	11.4	27.3
	Sure	17	38.6	38.6	65.9
	Very Sure	15	34.1	34.1	100.0
	Total	44	100.0	100.0	

Table 5.12: Descriptive analysis rainwater harvesting is safely to used

Chart 5.11 and Table 5.16 above show that there are 7 of respondent's unsure rainwater harvesting is safely to used and it is represent 40% at DID and 6.7% at NAHRIM. The percentage for fair/ moderate know rainwater harvesting is safely to use is 13.3% at DID and NAHRIM and 7.1% at KeTTHA and numbers of respondents is 5 people. 17 respondents sure rainwater harvesting is safely to use and among of percentage are 26.7% at DID, 46.7% at NAHRIM and 42% at KeTTHA. For very sure rainwater harvesting system are 20% at DID, 33.3% at NAHRIM and 50% at KeTTHA which mean 15 numbers of respondents. Therefore, total numbers of respondents are 44 people and there is no missing or deleted respondent. Total cumulative percentage is 100%.

5.2.3 Benefits of Rainwater Harvesting.

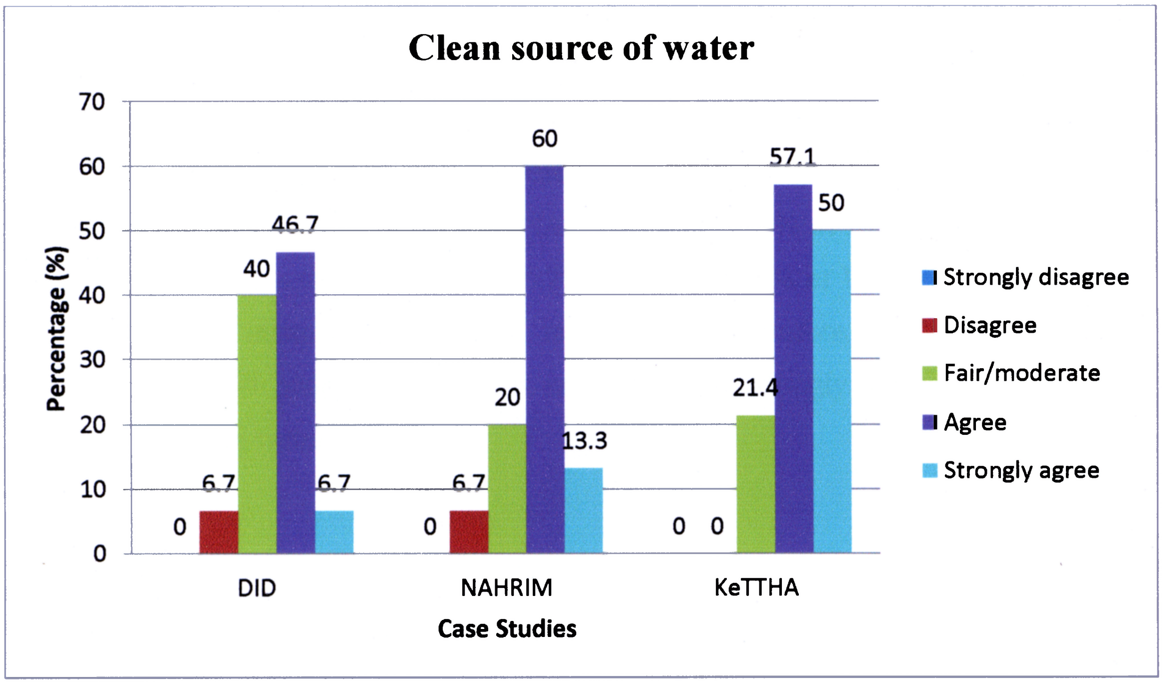


Chart 5.13: Descriptive analysis of rainwater harvesting is clean source of water.

Clean source of water

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	4.5	4.5	4.5
	Fair / Moderate	12	27.3	27.3	31.8
	Agree	24	54.5	54.5	86.4
	Strongly Agree	6	13.6	13.6	100.0
	Total	44	100.0	100.0	

Table 5.17: Descriptive analysis of rainwater harvesting is clean source of water.

Table 5.17 and Chart 5.13 above show that there are 2 of respondent's disagree rainwater harvesting is clean source of water and it is represent 6.7% at DID and NAHRIM. 12 of respondent state that their fair/ moderate rainwater harvesting is clean water source are 40% at DID, 40% at NAHRIM and 21.4% at KeTTHA. 24 respondents agree about rainwater harvesting is clean water sources and among of percentage are 46.7% at DID, 60% at NAHRIM and 57.1% at KeTTHA. For very agree rainwater harvesting system are 6.7% at DID, 13.3% at NAHRIM and 50% KeTTHA which mean 6 numbers of respondents. Therefore, total numbers of respondents are 44 people and there is no respondent strongly disagree rainwater harvesting is clean water sources.

According to Khoury-Nolde, nd, rainwater is free and clean water sources are proven from analysis above because 30 respondents agree and strongly agree with Khoury-Nolde rainwater is clean water sources. Thus rainwater harvesting is a clean of water sources. For observation, rain water harvesting is not used as portable but is used as non-portable water such as flushing toilet and landscape irrigation.

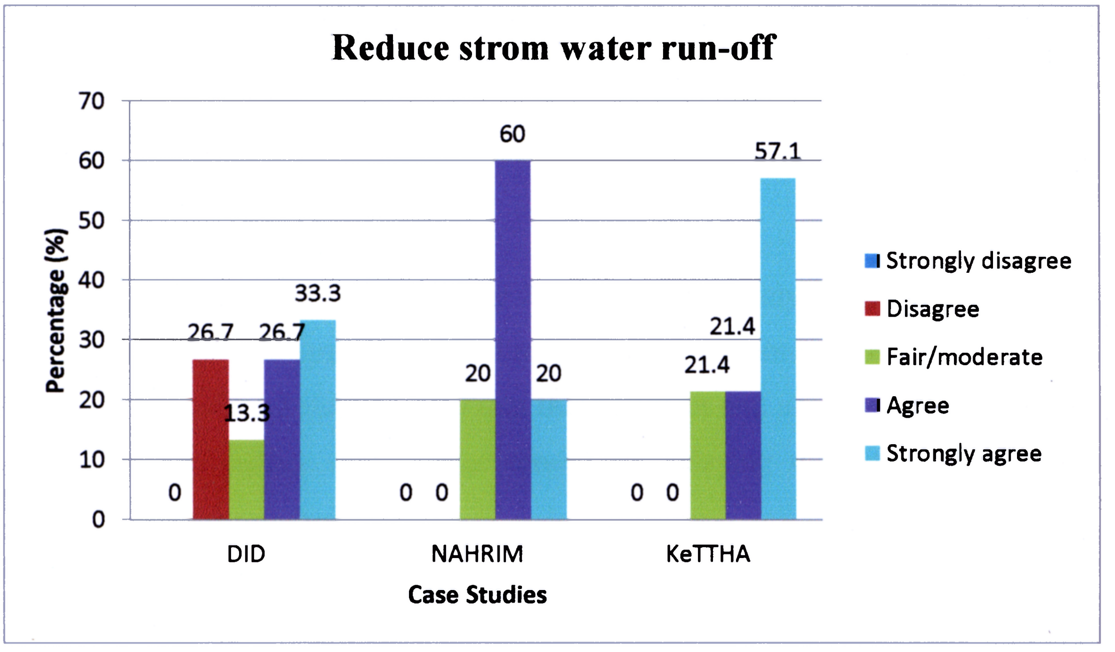


Chart 5.14: Descriptive analysis of rainwater harvesting can reduce storm water runoff.

Reduce storm water runoff

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	4	9.1	9.1	9.1
	Fair / Moderate	10	22.7	22.7	31.8
	Agree	21	47.7	47.7	79.5
	Strongly Agree	9	20.5	20.5	100.0
	Total	44	100.0	100.0	

Table 5.18: Descriptive analysis of rainwater harvesting can reduce storm water runoff.

Based on the table 5.18 and chart 5.14 above, represent rainwater harvesting system can reduce storm water run-off and 4 of respondents is disagree rainwater harvesting system can reduce storm water run-off (26.7% at DID), 10 respondents in fair/moderate scale (13.3% at DID, 20% at NAHRIM and 21.4% at KeTTHA), 21 respondents is agree with the benefit of rainwater harvesting system (26.7 T DID, 60% at NAHRIM and 21.4% at KeTTHA%) and 9 respondents strongly agree rainwater harvesting system can reduce storm water run-off (33.3% at DID, 20% at NAHRIM and 57.1% at KeTTHA). Thus, majority of respondents agree rainwater harvesting system can reduce storm water run-off.

According from NAHRIM, September 2010, a desktop study on impact of rainwater harvesting utilization system on flood reduction found, rainwater harvesting has big potentials for utilized flash flood. From the statement and analysis above, rainwater harvesting can reduce storm water run-off by delaying time rainwater flow or discharge to drainage and river.

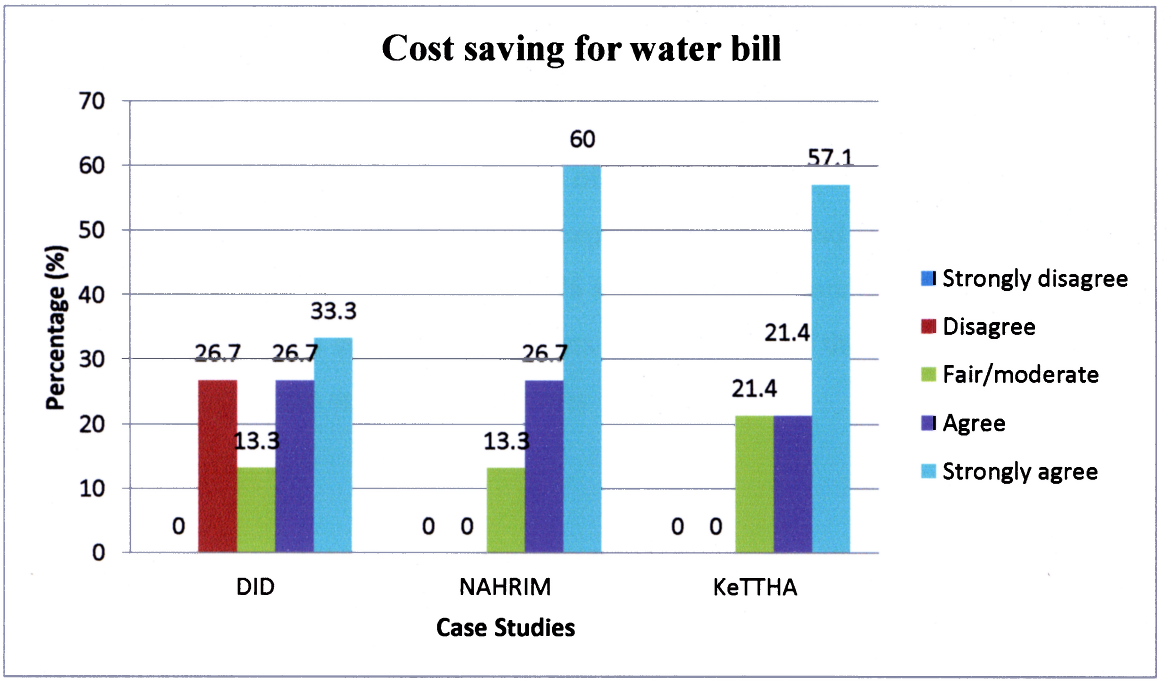


Chart 5.15: Descriptive analysis of rainwater harvesting system can be as costs saving for water bill.

Cost saving for water bill

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	4	9.1	9.1	9.1
	Fair / Moderate	7	15.9	15.9	25.0
	Agree	11	25.0	25.0	50.0
	Strongly Agree	22	50.0	50.0	100.0
	Total	44	100.0	100.0	

Table 5.19: Descriptive analysis of rainwater harvesting system can be as costs saving for water bill.

According to the Table 5.19 and Chart 5.15 above, 4 respondents or 26.7% at DID respondent disagree rainwater harvesting can be as costs saving for water bill, 7 respondents or 13.3% at DID and NAHRIM and 21.4% at KeTTHA respondents stated fair/moderate rainwater harvesting system can be as costs saving for water bill, 11 respondents had agree with the benefits of rainwater harvesting or 26.7% at DID and NAHRIM and 21.4% at KeTTHA respondents agree and 22 respondents or 33.3% at DID, 60% at NAHRIM and 57.1% at KeTTHA respondents strongly agree rainwater harvesting can save water bill costs. The majority of the respondents agree rainwater harvesting can save water bill costs.

According to NAHRIM, rainwater harvesting system at RM 1.63/m3 is cheaper compared with the piped water cost of RM 1.70/m3. Rate of rainwater harvesting system consider installation and supply costs according to materials usage. Tariff RM 1.63/m3 based from total cost installation over water saving. Installation of rainwater harvesting system made on 2 storey terrace house at 2001. From the chart, majority agree with NAHRIM estimating and calculation that rainwater harvesting can save water bill cost.

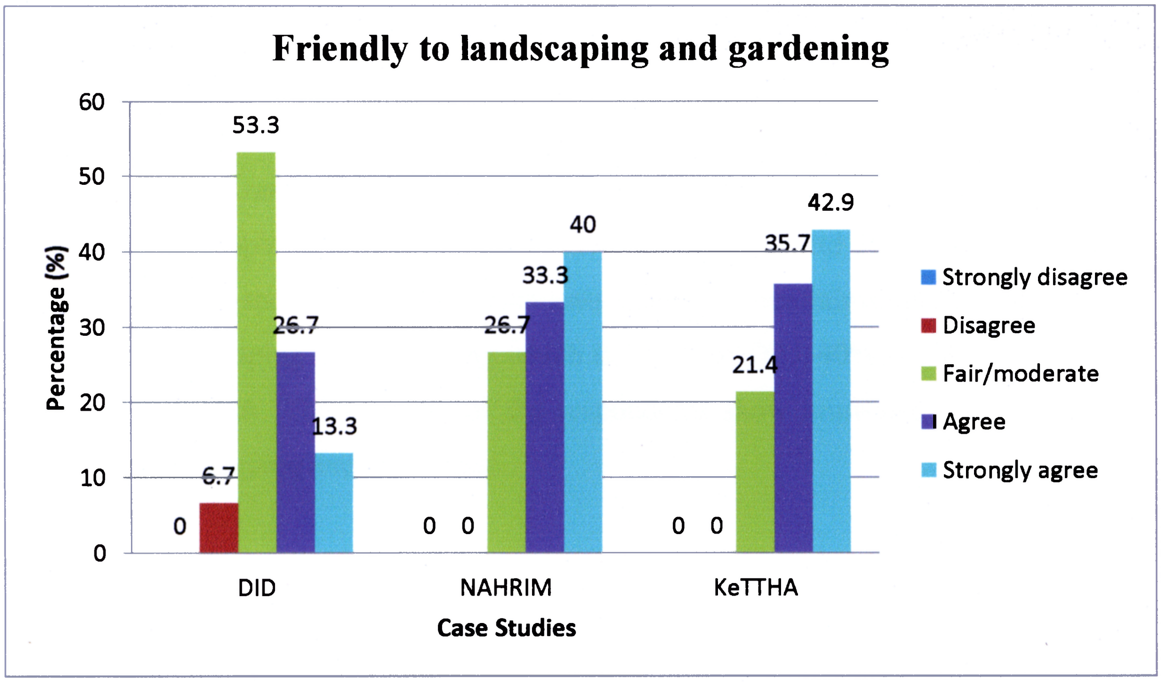


Chart 5.16: Descriptive analysis of rainwater harvesting system is friendly to landscaping and gardening

Friendly to landscaping and gardening

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	2.3	2.3	2.3
	Fair / Moderate	15	34.1	34.1	36.4
	Agree	14	31.8	31.8	68.2
	Strongly Agree	14	31.8	31.8	100.0
	Total	44	100.0	100.0	

Table 5.20: Descriptive analysis of rainwater harvesting system is friendly to landscaping and gardening

From the Table 5.20 and Chart 5.16 below, the summarized that 1 respondent or 6.7% at DID disagree rainwater harvesting is friendly to landscaping and gardening, 15 people or 53.3% at DID, 26.7% at NAHRIM and 21.4% at KeTTHA respondent stated rainwater harvesting is fair/ moderate friendly to landscaping and gardening, 14 people or 26.7% at DID, 33.3% at NAHRIM and 35.7% at KeTTHA of the respondent stated agree. 14 respondents strongly agree rainwater harvesting is friendly to landscaping and gardening which is 13.3% at DID, 40% at NAHRIM and 42.9% at KeTTHA. The majority of the respondents show rainwater harvesting is friendly to landscaping and gardening.

The analysis support by Helmreich & Horn, 2008, harvested rainwater can be source in households for drinking, cooking, sanitation, as well as for productive use in agriculture and landscape watering.

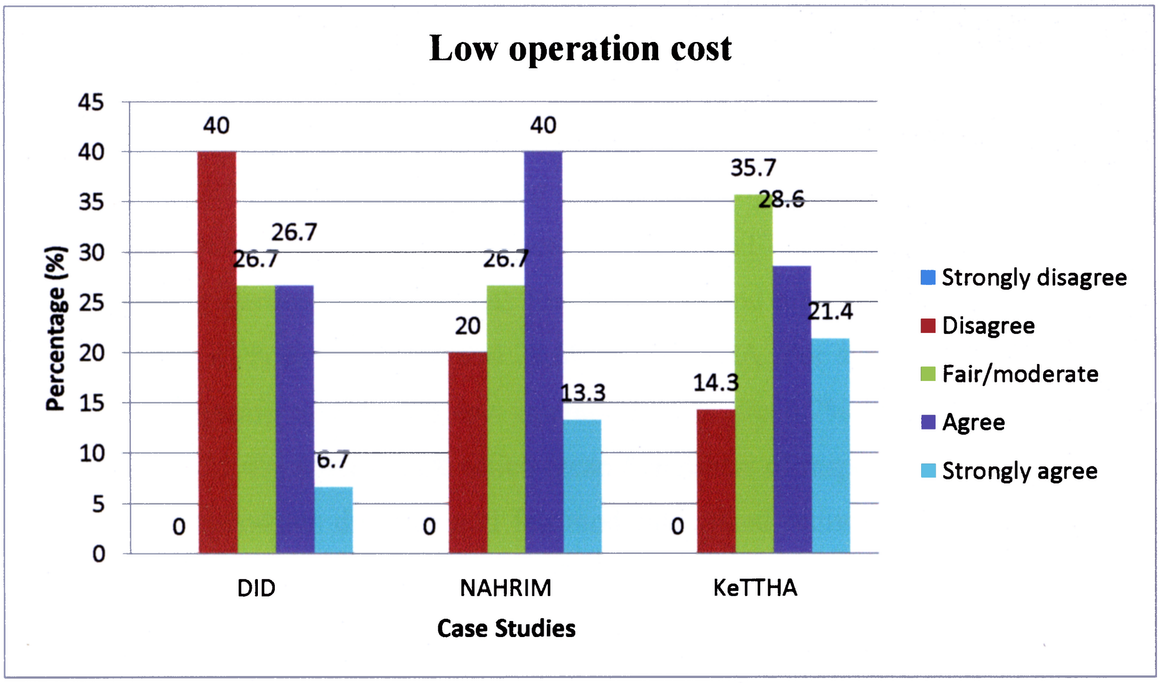


Chart 5.17: Descriptive analysis of rainwater harvesting system has low operation costs.

Low operation cost

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	11	25.0	25.0	25.0
	Fair/ Moderate	13	29.5	29.5	54.5
	Agree	14	31.8	31.8	86.4
	Strongly Agree	6	13.6	13.6	100.0
	Total	44	100.0	100.0	

Table 5.21: Descriptive analysis of rainwater harvesting system has low operation costs.

Table 5.21 and Chart 5.17 above show that there are 11 of respondent's disagree rainwater harvesting system has low operation costs and it is represent 40% at DID, 20% at NAHRIM and 14.3% at KeTTHA. 13 of respondent state that their fair/moderate about rainwater harvesting system has low operation costs and it is represent 26.7% at DID and NAHRIM and 35.7% at KeTTHA. 14 respondents sure about rainwater harvesting system has low operation and among of percentage are 26.7% at DID, 40% at NAHRIM and 28.6% at KeTTHA. For strongly agree about rainwater harvesting system has low operation costs are 6.7% at DID, 13.3% at NAHRIM and 21.4% at KeTTHA which mean 6 numbers of respondents. Therefore, majority of respondents disagree and fair/moderate stated rainwater harvesting has low operation costs. Low running costs for rainwater harvesting system (Khoury-Nolde, nd) is not represent from this analysis.

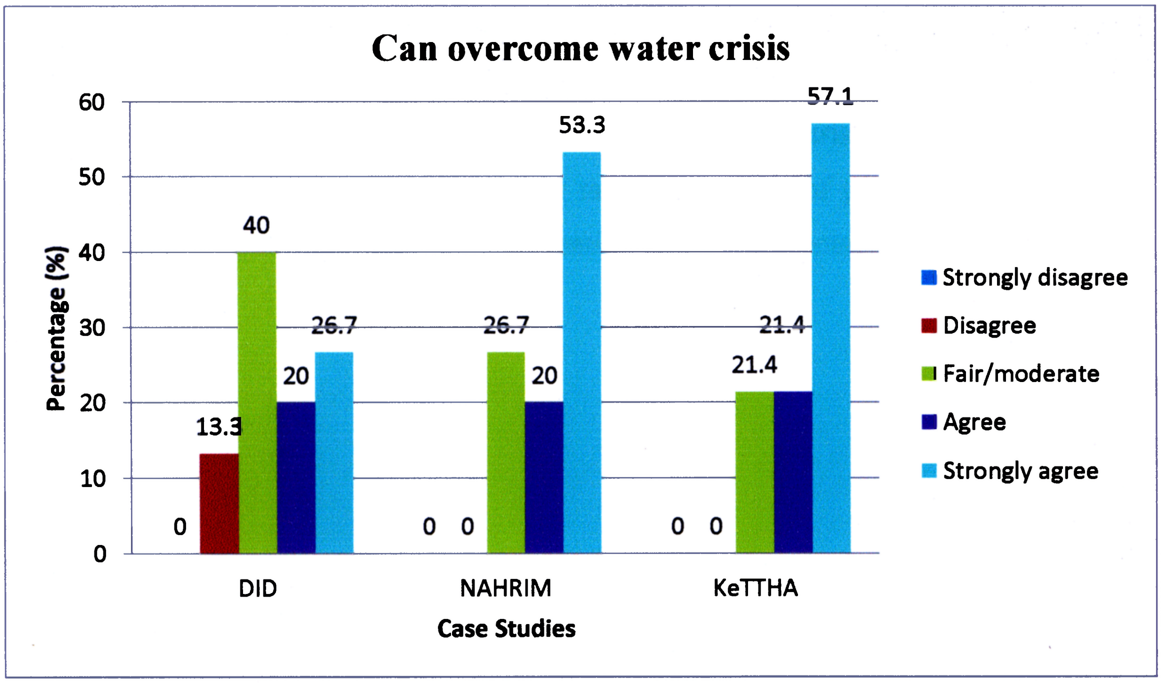


Chart 5.18: Descriptive analysis of rainwater harvesting system can overcome water crisis.

Can overcome water crisis

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	4.5	4.5	4.5
	Fair / Moderate	13	29.5	29.5	34.1
	Agree	9	20.5	20.5	54.5
	Strongly Agree	20	45.5	45.5	100.0
	Total	44	100.0	100.0	

Table 5.22: Descriptive analysis of rainwater harvesting system can overcome water crisis.

The above Table 5.22 and Chart 5.18 showed the analysis rainwater harvesting can overcome water crisis. There are 2 respondents or 13.3% at DID disagree rainwater harvesting can overcome water crisis, 13 respondents or 40% from DID, 26.7% from NAHRIM and 21.4% at fair/moderate stated rainwater harvesting can overcome water crisis, 9 respondents or 20% from DID, 20% from NAHRIM and 21.4% from KeTTHA agree rainwater harvesting can overcome water crisis and 20 respondents or 26.7% from DID, 53.3% from NAHRIM and 57.1% from KeTTHA strongly agree rainwater harvesting can overcome water crisis. The majority agree rainwater harvesting can overcome water crisis and support by Chistina, 2008 stated the abundant annual rainfall, scarcity of potable surface and ground water suggests that rainwater harvesting has a huge potential to solve fresh water scarcity.

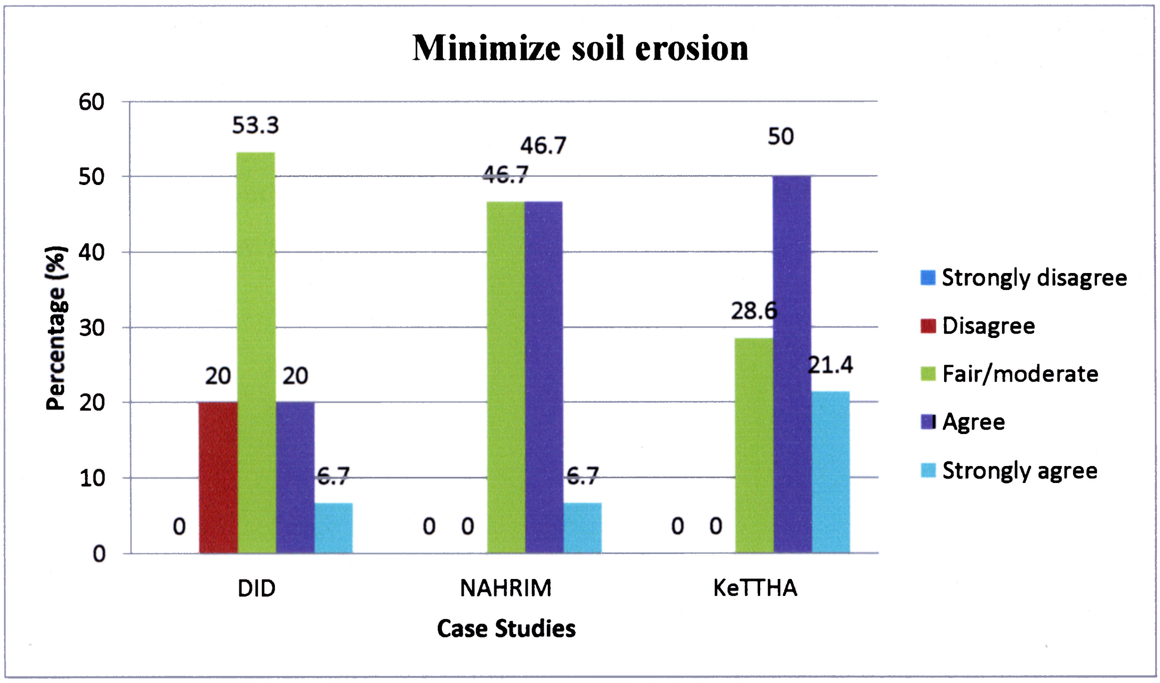


Chart 5.19: Descriptive analysis of rainwater harvesting system can minimize soil erosion.

Minimize soil erosion

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	3	6.8	6.8	6.8
	Fair / Moderate	19	43.2	43.2	50.0
	Agree	17	38.6	38.6	88.6
	Strongly Disagree	5	11.4	11.4	100.0
	Total	44	100.0	100.0	

Table 5.23: Descriptive analysis of rainwater harvesting system can minimize soil erosion

From the Table 5.23 and Chart 5.19 above, can be summarized that 3 respondents or 20% from DID disagree rainwater harvesting can minimize soil erosion, 19 people or 53.3% from DID, 46.7% from NAHRIM and 28.6% from KeTTHA respondent in fair/ moderate state, 17 people or 20% from DID, 46.7% from NAHRIM and 50% from KeTTHA respondent agree rainwater harvesting can minimize soil erosion and 5 people or 6.7% from DID and NAHRIM and 21.4% from KeTTHA respondents strongly agree rainwater harvesting can minimize soil erosion. Half of majority agree rainwater harvesting can minimize soil erosion. According to Khoury-Nolde, nd, rainwater harvesting can minimize soil erosion and it is supported from analysis above.

5.2.4 Descriptive Analysis Problems and Barrier of Rainwater Harvesting System

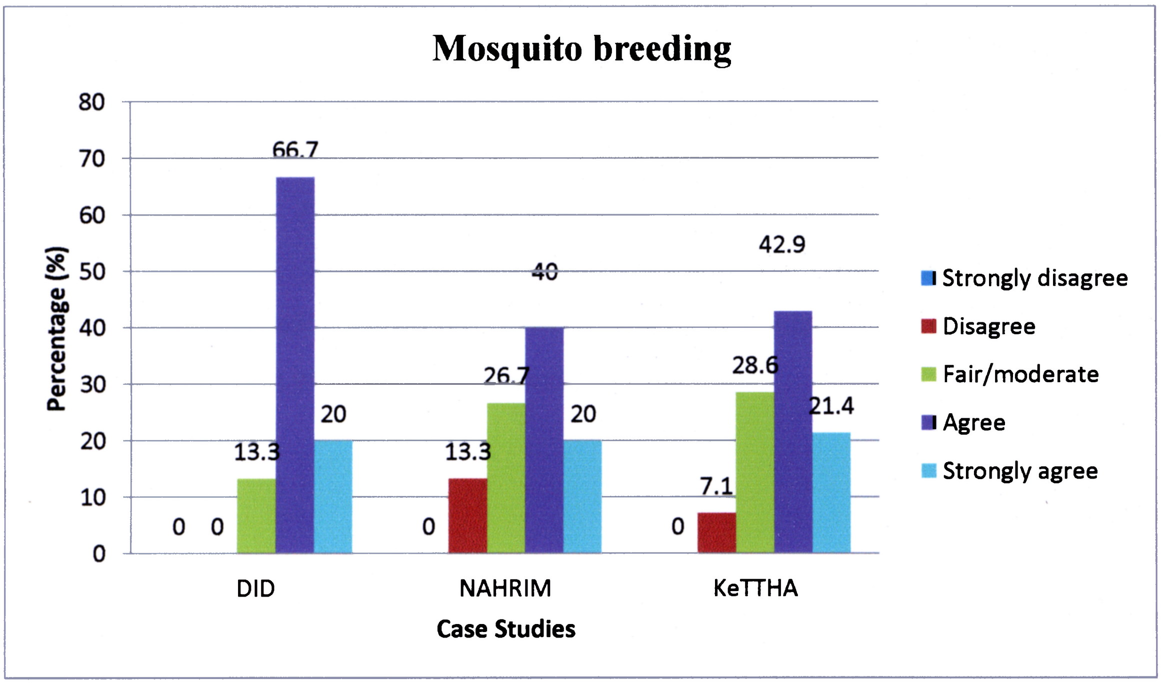


Chart 5.20: Descriptive analysis of rainwater harvesting system can cause mosquito breeding.

Mosquito breeding

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	3	6.8	6.8	6.8
	Fair / Moderate	10	22.7	22.7	29.5
	Agree	22	50.0	50.0	79.5
	Strongly Agree	9	20.5	20.5	100.0
	Total	44	100.0	100.0	

Table 5.24: Descriptive analysis of rainwater harvesting system can cause mosquito breeding.

Based on the table 5.24 and chart 5.20 above shown 3 respondents disagree mosquito breeding is a problems of rainwater harvesting (13.3% from NAHRIM and 7.1% from KeTTHA), 10 respondents fair/ moderate (13.3% from DID, 26.7% from NAHRIM and 28.6% from KeTTHA), 22 respondents agree mosquito breeding is a problems of rainwater harvesting (66.7% from DID, 40% from NAHRIM and 42.9% from KeTTHA) and 9 respondents strongly agree mosquito breeding is a problems of rainwater harvesting (20% from DID and NAHRIM and 21.4% from KeTTHA). According to Mohd. Shahwahid et al, 2007, mosquito breeding is a factor to implementing rainwater harvesting system cannot be enhance. Thus, mosquito breeding is a problem of rainwater harvesting system.

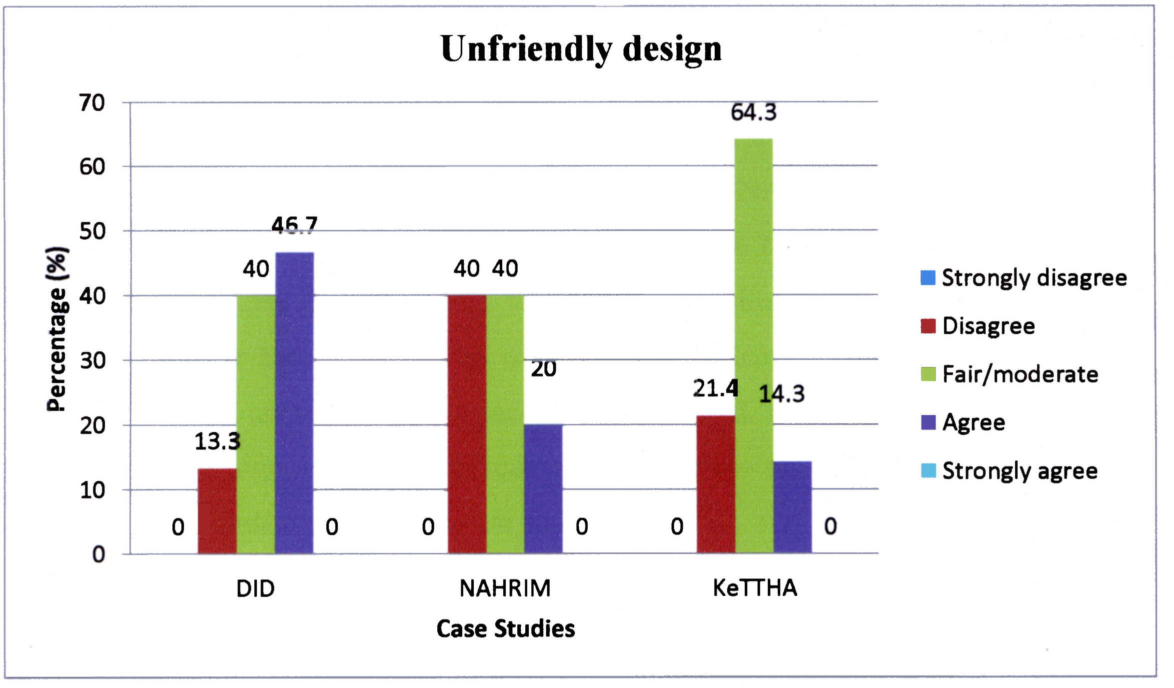


Chart 5.21: Descriptive analysis of rainwater harvesting system has unfriendly design and takes much space.

Unfriendly design and take much space

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	11	25.0	25.0	25.0
	Fair / Moderate	21	47.7	47.7	72.7
	Agree	12	27.3	27.3	100.0
	Total	44	100.0	100.0	

Table 5.25: Descriptive analysis of rainwater harvesting system has unfriendly design and takes much space.

Based on the Table 5.25 and Chart 5.21 above, for descriptive analysis of rainwater harvesting system has unfriendly design and takes much space, there are 11 respondents or 13.3% from DID, 40% from NAHRIM and 21.4% from KeTTHA was disagree, 21 respondents or 40% from DID and NAHRIM and 64.3% from KeTTHA was fair/moderate and 12 respondents or 46.7% from DID, 20% from NAHRIM and 14.3% from KeTTHA was agree. According to Mohd. Shahwahid et al, 2007 rainwater harvesting system is difficult to implement due to the unfriendly design which had taken too much space in the backyard. Based on analysis, proper planning and design might be overcome this problem and from analysis above majority of respondent in fair/moderate state.

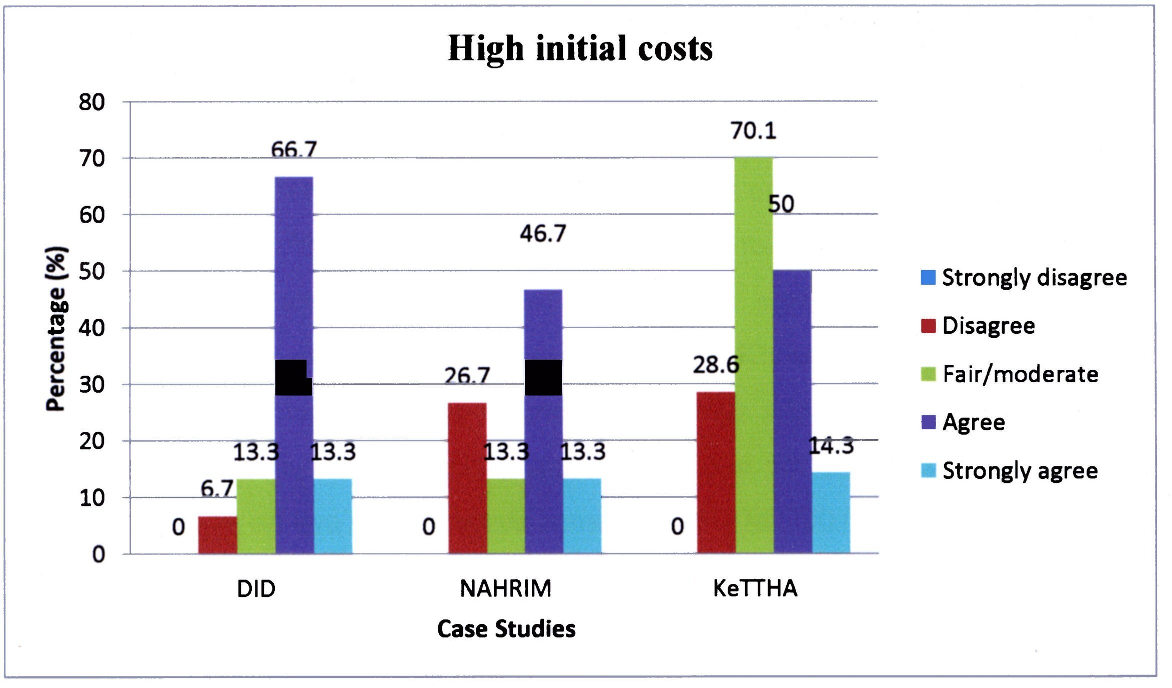


Chart 5.22: Descriptive analysis of rainwater harvesting system has high initial costs.

High initial cost for installation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	9	20.5	20.5	20.5
	Fair / Moderate	5	11.4	11.4	31.8
	Agree	24	54.5	54.5	86.4
	Strongly Agree	6	13.6	13.6	100.0
	Total	44	100.0	100.0	

Table 5.26: Descriptive analysis of rainwater harvesting system has high initial costs.

The above Table 5.26 and 5.22 showed rainwater harvesting system has high initial costs. There are 9 respondents or 6.7% from DID, 26.7% from NAHRIM and 28.6% from KeTTHA disagree, 5 respondents or 13.3% from DID and NAHRIM and 70.1% from KeTTHA fair/moderate, 24 respondents or 66.7% from DID, 46.7% from NAHRIM and 50% from KeTTHA agree and 6 respondents or 13.3% from DID and NAHRIM and 14.35 from KeTTHA strongly agree. The majority agree rainwater harvesting system has high initial costs. . Khoury-Nolde, initial costs installation of rainwater harvesting depends on materials selection during designing the system. According to NAHRIM, approximate cost for installation rainwater harvesting system on two storey terrace house around RM2700.00 and the return in 15 years to 16 years, cost estimate in year 2001. Therefore, initial costs of rainwater harvesting can be control by materials selection and design system of rainwater harvesting.

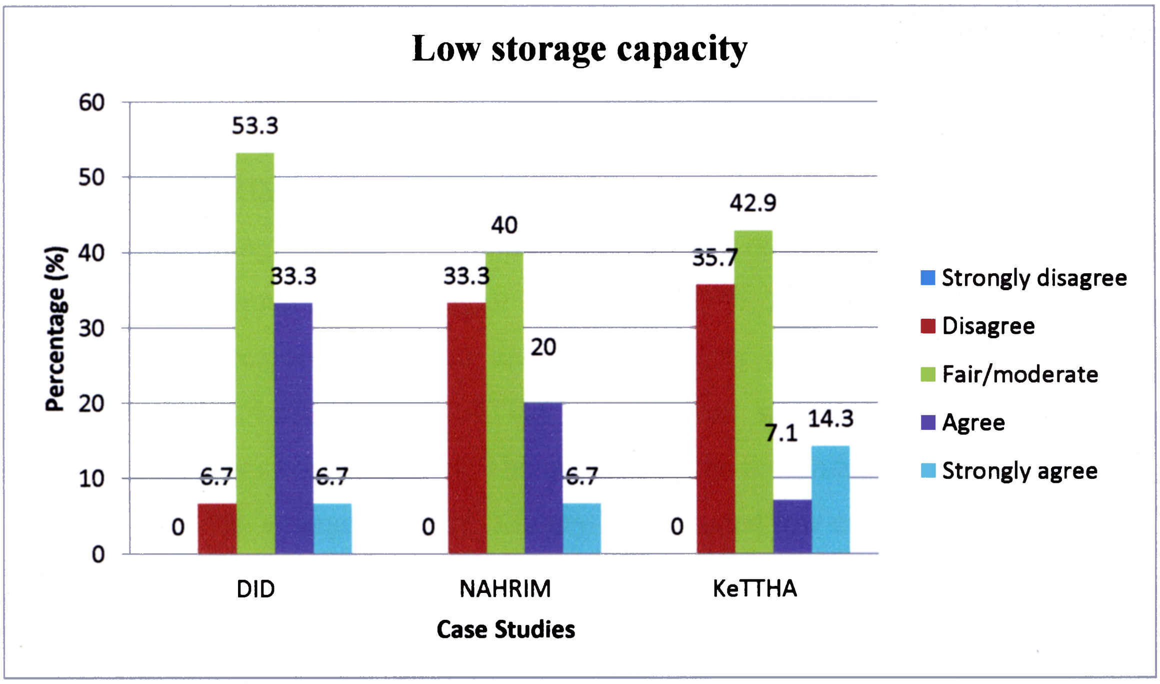


Chart 5.23: Descriptive analysis of rainwater harvesting system has low storage capacity.

Low storage capacity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	11	25.0	25.0	25.0
	Fair / Moderate	20	45.5	45.5	70.5
	Agree	9	20.5	20.5	90.9
	Strongly Agree	4	9.1	9.1	100.0
	Total	44	100.0	100.0	

Table 5.27: Descriptive analysis of rainwater harvesting system has low storage capacity.

According to the Table 5.27 and Chart 5.23 above, 11 respondents or 6.7 % from DID, 33.3% from NAHRIM and 35.7% from KeTTHA respondent disagree rainwater harvesting has low storage capacity, 20 respondents or 53.3% from DID, 40% from NAHRIM and 42.9% from KeTTHA respondents stated fair/moderate rainwater harvesting system has low storage capacity, 9 respondents had agree with the benefits of rainwater harvesting or 33.3% from DID, 20% NAHRIM and 7.1% from KeTTHA respondents agree and 4 respondents or 6.7% from DID and NAHRIM and 14.3% from KeTTHA respondents strongly agree rainwater harvesting has low storage capacity. The majority of the respondents agree rainwater harvesting has low storage capacity. Khoury-Nolde stated low capacity storage will limit rainwater to harvested, thus, rainwater harvesting storage has low storage capacity and require large of storage. Storage of rainwater harvesting is based on design and numbers of usage, higher number of usage, and the bigger storage tank is needed.

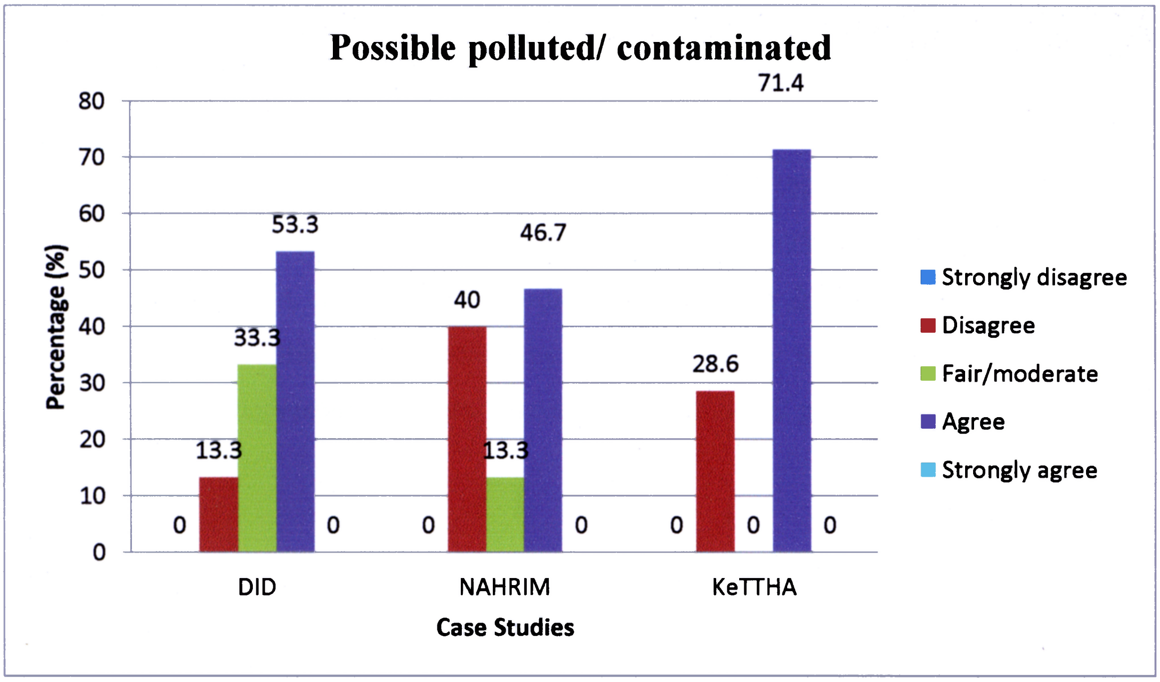


Chart 5.24: Descriptive analysis of rainwater harvesting system possible contaminated/ polluted.

Rainwater possible contaminated/ polluted

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	12	27.3	27.3	27.3
	Fair / Moderate	7	15.9	15.9	43.2
	Agree	25	56.8	56.8	100.0
	Total	44	100.0	100.0	

Chart 5.28: Descriptive analysis of rainwater harvesting system possible contaminated/ polluted.

Based on the Table 5.28 and Chart 5.24 above, for descriptive analysis of rainwater harvesting system possible contaminated/ polluted, there are 12 respondents or 13.3% from DID, 40% from NAHRIM and 28.6% from KeTTHA was disagree, 7 respondents or 33.3% from DID and 13% from NAHRIM was fair/moderate and 25 respondents or 53.3% from DID, 46.7% from NAHRIM and 71.4% from KeTTHA was agree. According to Helmreich & Horn, 2008, in urban area, rainwater possibly contaminated by particles, heavy metals and organic air pollutants. Thus, harvested rainwater possibly contaminated/ polluted according data analysis above.

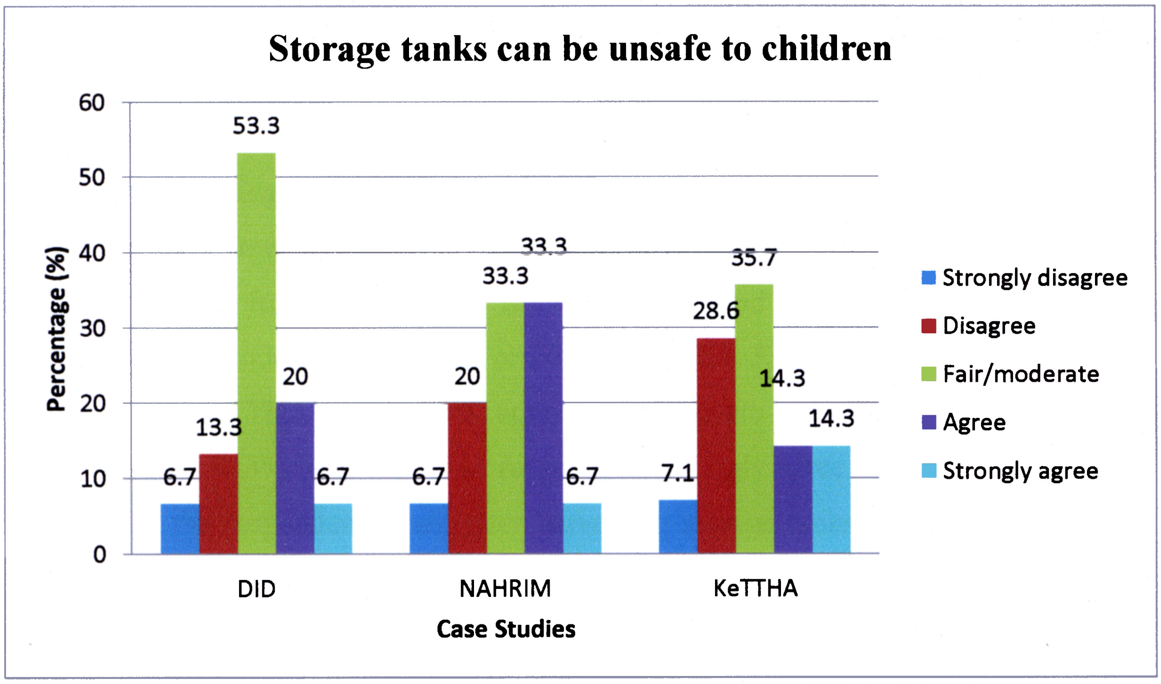


Chart 5.25: Descriptive analysis of rainwater harvesting storage tanks can be unsafe for children

Storage tanks can be unsafe for children

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	6.8	6.8	6.8
	Disagree	9	20.5	20.5	27.3
	Fair / Moderate	18	40.9	40.9	68.2
	Agree	10	22.7	22.7	90.9
	Strongly Agree	4	9.1	9.1	100.0
	Total	44	100.0	100.0	

Table 5.29: Descriptive analysis of rainwater harvesting storage tanks can be unsafe for children

From the Table 5.29 and Chart 5.25 above can summarized that 3 respondent or 6.7% from DID and NAHRIM and 7.1% from KeTTHA strongly disagree rainwater harvesting storage tanks can be unsafe for children, 9 people or 13.3% from DID, 20% from NAHRIM and 28.6% from KeTTHA respondent disagree, 18 people or 53.3% from DID, 33.3% from NAHRIM and 35.7% from KeTTHA respondent fair/moderate, 10 people or 20% from DID, 33.3% from NAHRIM and 14.3% from KeTTHA respondents agree and 4 people or 6.7% from DID and NAHRIM and 14.3% from KeTTHA respondents strongly agree. The one over third majority of the respondent's rainwater harvesting storage tanks can be unsafe for children. Storage tanks can be unsafe for small children if proper access protection is not provided (Khoury-Nolde, nd), thus, storage tank is not dangerous to children if proper access provided.

CHAPTER 6

CHAPTER 6

6.1 INTRODUCTION

The purpose of this chapter is to review the study including a discussion of a key findings, conclusion, and recommendations. This research was a quantitative study which investigated problems and barrier to implement and enhance rainwater harvesting system for overcome water crisis in Klang Valley. The conclusion will give an overall view regarding this research as a whole rely on the result from the analysis. The implication of the findings also had been analysing during do the research. The suggestion to overcome problems and barriers and recommendation will be propose that rainwater harvesting system can be implement in Malaysia and more specific in Klang Valley.

6.2 DISCUSSION

The purpose of this study is to measure knowledge about rainwater harvesting system. Furthermore, this study is to identify benefits and potential of rainwater harvesting to overcome water crisis in Klang Valley. Besides that, identify of problems and barriers of rainwater harvesting is an objectives for this study. In the following discussion, results of each objective are reviewed and compared with previous literature.

Objective 1: To identify system of rainwater harvesting that used at case studies building.

From finding and analysis, different system of rainwater harvesting such as gravity system and pump sytem has same issues and problem which is failure on water gauge. Water gauge is used to measure water level in storage tank that allow supply from SYABAS fill in storage during harvested rainwater in minimum level.

Objective 2: To identify knowledge people about rainwater harvesting system in Klang Valley.

From the findings, it can be concluded that level of knowledge about rainwater harvesting in Malaysia is high. Majority of respondent know the about system of rainwater harvesting, operation of the system and flexibility of the system

Objective 3: To identify the benefits of rainwater harvesting system in Klang Valley.

The results of this study indicate a positive opportunity of rainwater harvesting system to overcome water crisis in Malaysian. The benefits and potential of rainwater harvesting from past research is proven in this study. The development rainwater harvesting system is passing toward with development of technologies.

Rainwater harvesting system can be a clean water sources and it will contribute cost saving for water bill. Harvested rainwater also environment friendly system and with this system water crisis, flood crisis and soil erosion can be overcome.

Objective 4: To identify problems, barriers or any inadequate that associated with rainwater harvesting system.

From this study, problems and barrier of rainwater harvesting has no evidence and it was not been proven. Mosquito breeding in storage tank can be overcome by proper maintenance of the storage tank. Besides that, rainwater harvesting has affordable initial cost because installation of rainwater harvesting depends on materials selection, numbers of user and design of system.

5.3 CONCLUSIONS

Rainwater harvesting have a potential in developing countries especially in Malaysia to solve development impacts due to the beneficial of the system. Rainwater harvesting system can be adapt for agriculture purpose, domestic purpose and minimizing development impacts such as storm water and water scarcity. This study lead onto system of rainwater harvesting, benefits and problems and barriers of rainwater harvesting opportunity to be implement. During carry out this study, main obstacle is numbers of building that has been implement rainwater harvesting is small. Other difficulties to achieve goals for this study are difficulty to get permission to access the building was implementing this system; lack of information about building was implementing rainwater harvesting and cooperation of occupants of building. Besides that, building user of rainwater harvesting system also not realize and lack of knowledge of rainwater harvesting on the building.

The occupants of building have less expose about the system that has be using on the building, benefits of rainwater harvesting, problems and barriers on the system and operations of the rainwater harvesting system. Less of expose about rainwater harvesting was implement on the building occur causes by the management may not notify the occupants of the building. Less of awareness about rainwater harvesting system may to lead the occupants of building lack of knowledge.

Benefits of rainwater harvesting system cannot be denied because from previous study has been stated and from this study once again benefits of rainwater harvesting will be highlight. The benefits of rainwater harvesting system are form respondents feedback and the respondents are occupants of building that has been implementing rainwater harvesting system. Form data analysis and findings, rainwater harvesting can minimize cost of water because flushing toilet make water consumption increase. Approximate 6litre per flushing water closet (WC) and the water will increase if water consumption increase. Thus, rainwater harvesting is suitable for flushing toilet and it wills minimize water consumption.

Secondly, rainwater harvesting can overcome water crisis because average rainfall in Malaysia is one day per week and approximate 2000m³ per years the data get from DID. Water crisis in Klang Valley is not due to capacity of water at dam but due to increasing population in Klang Valley and poor of maintenance on motor pump house that supply water to user. Rainwater harvesting also is friendly to landscaping and gardening and simple and flexible technology that makes easy to operate and manage the system. Other benefits of rainwater harvesting is reducing storm water run-off. According to NAHRIM rainwater harvesting can reduce storm water run-off and float and a desktop study has been carry out in Damansara.

Rainwater harvesting also is a clean water sources that suitable to portable and non-portable purpose. Rainwater is from hydrology circle process. Hydrology circle is a process evaporation of water from pond, lake, river or etc. and produce clouds before rainwater fall by process condensation. Rainwater harvesting system is easy to operate and manage and also low operation cost because it has simple technology. Thus, rainwater harvesting seems to be beneficial human and environment.

Rainwater harvesting is beneficial to human and environment, thus, this system has problems and barriers need to improve in future. Problems and barriers of rainwater harvesting are mosquito breeding and it is high rating from respondents. High initial cost for installation of rainwater harvesting and follow by harvested rainwater may pollute and contaminated. Besides that, rainwater harvesting system are unsafe for children and its take much space in backyard. Thus, rainwater needs solutions of problems and barriers on the system to ensure better system to implementing rainwater harvesting in Malaysia.

Therefore, rainwater harvesting has potential in Malaysia due to climate and other factors make rainwater harvesting system is needed. Rainwater harvesting has lot benefits to human and environment and its needs improvement on the system.

5.5 RECOMMENDATIONS

This subtopic will include recommendation for improvement of rainwater harvesting system and extend study for rainwater harvesting system. From improvement and innovation of rainwater harvesting system may include material selection form storage tank components and conveyor system.

Material is important aspect that ensures rainwater harvesting will be operation and manage in minimum cost. From case studies, problems of selecting unsuitable materials make the operation of the system is interrupted. Materials selection should consider reaction the material with rainwater and durability of material. For example, HDPE storage has high durability and workability for installation and the materials is not has chemical reaction with rainwater.

Conveyor system is a component of rainwater harvesting that deliver rainwater to storage tank. Conveyor system should have same aspect with storage tank and addition storage tank should suitable with catchment to avoid over flow rainwater.

For recommendation extend study, designing of rainwater harvesting system adapted with climate and size of user. Designing of rainwater harvesting system may lead this system more effective and efficient with installation cost, operation cost and management costs. Designing of rainwater harvesting also make quality of water can be sustain and avoid quality of deceasing. Designing of rainwater harvesting system may influence quality of water, initial costs, storage capacity and others.

Thus, benefits, problems and barriers of rainwater harvesting system can overcome by suitable design system, awareness of public, materials selections and government enforcement and policies.

REFFERENCES

REFERENCE

Coombes, P., Kuczera, G., Kalma, J. (2000). Rainwater Quality from Roofs Tanks and Hot Water Systems at Fig Tree Place. Proceedings of the 3rd International Hydrology and Water Resources Symposium, Perth. (http://rambler.newcastle.edu.au/%7Eecegak/Coombes/Hydro20003.htm)

Department of Consumer & Business Services, (n.d.). Building codes division oregon smart guide building codes division rainwater harvesting. Retrieved from website: www.bcd.oregon.gov

Faisst, E.W., Fujioka, R. S. (1994). Assessment of four rainwater catchment designs on cistern water quality. In: Proceedings of the 6th international conference on rainwater catchment systems, Nairobi, Kenya. Eds. Bambrah, G.K., Otieno, F.O., Thomas, D.B. pp 399-407.

Fujioka, R.S. (1994). Guidelines and Microbial Standards for Cistern Waters. *In*: Proceedings of the 6th international conference on rainwater catchment systems, Nairobi, Kenya. Eds. Bambrah, G.K., Otieno, F.O., Thomas, D.B. pp 393-398.

Ghisi E and Ferreira D. F. (2006). "Savings by Using Rainwater and Grey Water in a Multi Storey Residential Building in Southern Brazil" Journal of Potential for Potable Water.

Gould J. and Nissen-Petersen, E. (1999). "Rainwater Catchment Systems for Domestic Supply" Intermediate Technology Pubs, UK.

Handia L, Tembo, J.M., Mwindwa, C. (2002) "Potential of Rainwater Harvesting in Urban Zambia" proceedings of 3rd Water Net/Warfsa Symposium, Dar Es-Salaam.

Jitender Dev Sehgal, A Guide To Rainwater Harvesting in Malaysia, Rotary Club of Johor Bahru.

Khoury-Nolde, N. (n.d.). Rainwater harvesting.

Macomber, P.S.H. (2001). Guidelines on rainwater catchment systems for Hawaii. College of tropical agriculture and human resources, University of Hawaii, Manoa. Publication no. RM-12. (http://www2.ctahr.hawaii.edu/oc/freepubs/pdf/RM-12.pdf)

Mohammed, T. A., Mohd. Noor, M. J. M., & Ghazali, A. H. (2008). Checking the adequacy of rainwater harvesting system for housing and landscaping.

Mohd. Shahwahid, H. O., Suhaimi, A. R., Rasyikah, M. K., Ahmad Jamaluddin, S., Huang, Y. F., & Farah, M. S. (2007). Policies and incentives for rainwater harvesting in malaysia.

Mosley, L. (2005). *Water quality of rainwater harvesting systems.*

Otieno, F.A.O. (1994). Quantity and quality of runoff in Nairobi: the wasted resource. In: Proceedings of the 6th international conference on rainwater catchment systems, Nairobi, Kenya. Eds. Bambrah, G.K., Otieno, F.O., Thomas, D.B. pp 379-388.

Rahman M. M., Fatima J., (2006). "Challenges for Implementation of Rain Water Harvesting Project in Arsenic Affected Areas of Bangladesh" Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh.

Rainwater harvesting. Practical Action

Ruslan.H,(2003). " Rainwater Harvesting: Reliability Analyses for Large Buildings:Factory,Government and Commercial Complex", Universiti Teknologi MARA, Shah Alam, Malaysia.

Shaaban, A. J., Feng, H. Y., & Mohd Nasir, K. A. (2008). Potential and effectiveness of rainwater harvesting in enhancing the effectiveness of on-site detention (rosd) facilities in controlling surface runoff at taman wangsa melawati, kuala lumpur.

Shaaban, A. J., Kardi J., and Awang, S. (2002). "Rainwater Harvesting and Utilization System for A Double Story Terrace House at Taman Wangsa Melawati, Kuala Lumpur" A Workshop of Rainwater Harvesting as a Tool for Sustainable Water Supply and Stormwater Management, Kuala Lumpur, Malaysia.

United Nation 2002, World's water problem can be "catalyst for cooperation' says secretary-general in message on World Water Day. Press released SG/SM/8139 OBV/262, http://www.un.org/News/Press/docs/2002/sgsm8139.doc.htm.

Waterfall, P. H. (2006). *Harvesting rainwater.* (2nd ed.). Arizona: DOI: www.azwater.gov

Yaziz, M., Gunting, H., Sapiari, N., Ghazali, A. (1989). Variation in rainwater quality from roof catchments. *Water Research* 23: 761-765.

APPENDICES

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THE APPLICATION OF RAINWATER HARVESTING TO OVERCOME WATER CRISIS IN KLANG VALLEY.

This survey is to identify public knowledge about rainwater harvesting system, benefits, problems and barrier that associated to rainwater harvesting system in order to achieve objective for this study, Project Academic II. Please answer all question and follow the instruction are given.

A. General Information

Please mark (√) one from each question below.

I. Gender.

a. Male	
b. Female	

II. Age.

a. Below 20	
b. 21 – 30	
c. 31 - 40	
d. 41 - 50	

III. Occupation.

a. Engineer	
b. Architect	
c. Building manager	
d. Other.	

IV. Education level.

a. SPM	
b. Diploma/Degree	
c. Master	
d. PhD.	

V. Did you a rainwater harvesting user?

a. Yes	
b. No	

VI. Did you know about Rainwater Harvesting?

a. Yes	
b. No	

B. Knowledge of Rainwater Harvesting System

Please thick (√) for your chosen.

Very sure	5	Sure	4	Fair/ moderate	3	Unsure	2	Very unsure	1

	5	4	3	2	1
a. You know it work?					
b. Suitable for office and home					
c. Did you know where to install it?					
d. It has been used before in Malaysia					
e. It is safely to used					

C. Benefits of Rainwater Harvesting System

Thick (√) best answer that you choose.

Strongly agree	5	Agree	4	Fair/ moderate	3	Disagree	2	Strongly disagree	1

	5	4	3	2	1
a. Clean source of water					
b. Easy to operate and manage					
c. Reduce storm water runoff					
d. Cost saving for water bill					
e. Simple and flexible technology					
f. Friendly to landscaping and gardening					
g. Low operation cost					
h. Can overcome water crisis					
i. Minimize soil erosion					

D. Problems and Barriers of Rainwater Harvesting System

Please choose (√) the best answer.

Strongly agree	5	Agree	4	Fair/ moderate	3	Disagree	2	Strongly disagree	1

	5	4	3	2	1
a. Mosquito breeding					
b. Unfriendly design and take much space					
c. High initial cost for installation					
d. Low storage capacity					
e. Rainwater possible contaminated/ polluted					
f. Storage tanks can be unsafe for children					